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Effect of processing methods on utilization of feather meal by broiler chicks

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Effect of processing methods on utilization of feather meal by broiler chicks

by

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INTRODUCTION

The centralization of poultry processing has intensified the problem of disposal of poultry wastes. This, along with the concern over the world's protein needs and, more recently, man's environmental struggle, has been a strong persuasive factor in the development of poultry by-products. There is little doubt regarding the use of by-products from offal and blood in feedstuffs, but the same has not always been true for feathers. Keratinous proteins such as feathers, horn, hoof and hair are of little nutritional value in their native state. With proper processing, however, the keratin-type proteins can be made digestible and acceptable in animal feeds.

The concern over waste handling and preserving our environment is just one important aspect in recycling waste products produced in poultry processing plants. The world's ever increasing demand for protein is also of the utmost importance to the nutritionist today. The fact that animals have the ability to convert poor quality protein into high quality protein is well known. The substitution of poorer quality proteins for better proteins in poultry rations enables more of the better quality proteins to be channeled into other areas of use.

It is the responsibility of animal researchers to explore other products that can partially or totally substitute for some of the better protein sources that are now being used in animal feeds. It is no secret that more uses are being found for soybeans in food fit for human consumption. Since soybean meal is the primary protein source in poultry feeds

today in the United States, we in the field of poultry should be especially active in the area of developing new protein sources.

This series of experiments was designed to evaluate the effect of processing methods of feather meal on the value of these meals in broiler rations. Eight experiments were conducted to evaluate five feather meals, processed by the following specifications:

Designation	PSI	Time (min.)	Agitation
Feather meal A	40	30	Intermittent
Feather meal B	40	60	Intermittent
Feather meal C	50	30	Intermittent
Feather meal D	50	60	Intermittent
Feather meal E ("standard")	35	30	Constant

REVIEW OF LITERATURE

Nutritive Value of Feather Meal for Broiler Chicks

Feathers contain approximately 85% crude protein which, if made available, could supply many amino acids to the poultry diet. Block (1939) analyzed unprocessed feather protein and found it to contain large amounts of glycine, cystine, arginine, and phenylalanine. Gregory et al. (1956) analyzed processed feathers for amino acid and vitamin composition. They found, in comparison to amino acid values of raw feather meal (Block, 1939), that amino acids in feather protein are relatively stable during steam pressure processing. An exception is cystine which shows a considerable loss after processing with steam and pressure. Raw feathers have been shown to contain about 8.8% of its protein as cystine. Commercial processing of feathers has been shown to decrease the cystine content to about 3.6% while there is little effect on other amino acids according to Gregory et al. (1956). The probable reason for cystine destruction is the destruction of disulfide bonds by heat and pressure. Moran et al. (1967) noted that autoclaving hog hair reduced the cystine content from 11% to 3.5% of the protein. However, he found that glycine was increased as a percent of the protein.

Routh (1942) studied the nutritive value of powdered chicken feathers for young rats and reported that the feather protein supported moderate growth when it was supplemented with methionine, lysine, histidine and tryptophan. Newell and Elvehjem (1947) reported that powdered chicken feathers allowed only poor growth when fed to chicks and rats.

Wilder et al. (1955) fed feather meal to chicks at levels from 2.4% to 6.2% of the dietary protein. They obtained excellent chick growth when feather meal supplied 2.4% of the protein along with an equal amount of protein derived from meat and bone scrap and the remainder from soybean meal, alfalfa meal and corn.

That feather meal has a good supplementary value in corn-soybean meal rations supplemented with methionine is not surprising when the amino acid composition is considered. While feather meal is low in methionine, lysine, tryptophan and histidine, these amino acids are quite adequate in rations composed primarily of corn and soybean meal, with the exception of methionine, which is marginal.

Fuller (1956) found that he was able to replace all the fish meal by feather meal in a practical broiler diet when the methionine levels were adequate. Romoser (1955) found that at least 2.5% of feather meal may be added to broiler diet, provided there are adequate concentrations of all essential amino acids. This suggested to him that feather meal may be a satisfactory source of nonprotein nitrogen.

Moran et al. (1966) found commercial feather meal proved equal to isolated soybean protein in promoting chick growth when fed as the sole source of protein (15%) and supplemented with four amino acids. They found the order of amino acid limitation to be methionine, lysine, histidine and tryptophan, respectively.

Naber and Morgan (1956) showed that feather meal could replace 25% of the protein in a broiler ration containing large amounts of soybean oil

meal and corn supplemented with methionine, fish meal and dry whey products. Excellent chick growth was obtained with no impairment of the dietary nitrogen utilization. In subsequent studies Naber et al. (1961) reported that when one-third of the crude protein in the basal diet was replaced with feather meal, methionine and lysine supplementation was required to restore adequate growth rate. They concluded that the failure to obtain maximum growth even with adequate amino acid supplementation may be due to the inability of the chick to digest and assimilate a major portion of the amino acids from the feather protein.

Gerry (1956) obtained good results when feather meal replaced part of the fish meal and/or soybean meal in a broiler ration. He also tested feather meals from five different plants and obtained similar results, thus indicating consistancy in the processing procedures. Sibbald et al. (1962) showed that feather meal was inferior in low-protein diets (15%) but was satisfactory if the basal protein level was adequate (19.5% - 23.3%). When the basal diet contained 19.5% protein, 3% soybean meal or 3% soybean meal plus 3% meat meal could be replaced by feather meal without detriment to the chicks. When a basal diet containing 23.3% protein was fed, as much as 6% of the soybean meal could be replaced by feather meal with no adverse effect on the chicks. Tsang et al. (1963) concluded that feather meal can be used in broiler rations containing 20% protein at levels of 4% of the diet. In rations containing 22-26% protein, up to 8% of the diet may be feather meal.

Menge et al. (1956) fed both feather meal and the ash derived from it and observed a significant growth response by chicks. This led him

to the conclusion that feather meal may contain an essential inorganic growth factor. Stephens et al. (1959) also obtained a growth response from feather meal ash. Romoser (1955) and Fuller (1956) have also reported an unidentified growth factor in feather meal. Harms and Goff (1957) indicated that an unidentified factor, necessary for normal hatchability, is present in feather meal. Sibbald et al. (1962) examined the relative values of feather meal and supplementary Zn since an inorganic growth factor had been suggested (Fuller 1956, Menge et al. 1956, Stephens et al. 1959) and because analysis shows feather meal to contain about 100 ppm Zn. Their findings indicated that the added nutritive value of the feather meal is not entirely due to its Zn content.

Wisman et al. (1958) showed that hydrolyzed feather meal, when used to replace one-sixth of the dietary protein in a 20% chick starter ration, gave satisfactory results. There was no supplementation with amino acids in any of their diets. They noted appreciable quantities of riboflavin, niacin, pantothenic acid and vitamin B_{12} stimulated growth equally when added to a vitamin B_{12}-deficient basal ration. This substantiates the findings of Gregory et al. (1956) that feather meal contains sufficient quantities of vitamin B_{12}.

Naber and Morgan (1956) showed an increase in nitrogen retention by chicks fed diets containing feather meal. They could not give an explanation for these results, however, since growth responses during the test periods were approximately the same for all test groups.

Processing Methods

Draper (1944) first tried treating feathers with sodium sulfide and sodium hydroxide. He showed that chicks fed a corn oil meal diet with 50% of the dietary protein (16%) derived from feather meal, which had been treated with sodium sulfide and sodium hydroxide, gained more and consumed more feed than the chicks fed each product alone. He also autoclaved feathers for 2 and 4 hours at 15 pounds pressure and for 6 and 8 hours at 20 pounds pressure. He found that autoclaving did not appear to have any effect on the nutritive value of feathers fed to chicks or rats. Moran et al. (1966) showed that ground raw feathers failed to support as good growth, regardless of amino acid supplementation, as did feathers autoclaved for 30 minutes at 121° C. and those treated with sodium sulfide. Feathers autoclaved for 18 hours at 121° C. and supplemented with amino acids supported moderated growth.

The development of a simple method for the production of a friable feather meal was first described by Binkley and Vasak (1951). They reported that a good product could be made easily when feathers were heated at 40 psi for one hour or 60 psi for one-half hour with constant agitation. The feathers were then dried and ground to produce a free-flowing meal. They note that above 60 psi the feathers tended to "gum" and were difficult to remove from the cooker. Therefore, a free-flowing meal was not produced under these conditions. Loss of product by volitalization is negligible during cooking except for small amounts of sulfur and nitrogen. The initial and final nitrogen are essentially the same when cooking is done

under conditions prescribed by Binkley and Vasak (1951).

McKerns and Rittersporn (1958) fed feather meal that had been processed with 50 pounds of steam pressure for one hour, dried and then ground. They found that hydrolyzed feather meal could substitute effectively in a commercial broiler corn-soybean meal diet at a level equivalent to 25% of the total protein in a 24% protein diet.

Moran et al. (1967) showed that raw hog hair, if used as the sole source of protein, did not support normal chick growth, regardless of amino acid supplementation. Replacing 5% of soybean meal protein by properly processed hog hair (50 psi for 30 minutes) in a corn-soybean meal diet resulted in chick growth and feed efficiency comparable with the basal diet. When the processed hog hair replaced all the soybean protein, severe growth depression resulted. This was rectified by supplementary lysine, methionine, tryptophan and glycine.

Gehle et al. (1967) conducted a series of experiments to evaluate hydrolyzed hog hair as a potential protein source for growing birds. They used hog hair samples processed for three different periods of time. When 2% hydrolyzed hog hair was provided in a diet containing adequate protein, the chicks were able to use both the standard or undercooked hydrolyzed hog hair equally well. When the protein level was suboptimal, chicks fed diets containing hydrolyzed hog hair did not grow as well nor was feed conversion as efficient as when birds consumed the basal ration. These researchers concluded that older chicks (4-8 weeks of age) made better use of hydrolyzed hog hair protein than did younger chicks (1-4 weeks of age).

Sullivan and Stephenson (1957) conducted a series of experiments to determine the effects of processing methods on the nutritive value of hydrolyzed poultry feathers. Seven hydrolyzed feather meal samples were investigated. They concluded that the processing methods, based on various steam pressure cooking procedures, had similar effects on the nutritive value of feather meal for growing chicks at all levels of usage (2.5, 5.0 and 7.5%). Diets containing 2.5% feather meal supported chick growth in every trial equivalent to that of chicks fed a corn-soybean meal diet. When feather meal was incorporated at the 5% level, in one out of five trials growth was decreased while in the other four trials, growth was equivalent to that on the corn-soybean meal diet. The addition of 7.5% feather meal to the diet significantly decreased chick growth response as compared with the corn-soybean group. The differences in growth response were small between different processing methods but the greatest growth rate was obtained from a product processed as follows: Feathers were dried, cooked with 35 pounds steam pressure for 60 minutes, then dried and ground. Sullivan and Stephenson (1957) concluded that as little as 15 pounds of steam pressure for 20 minutes is effective in improving the feather protein for chick nutrition.

Naber et al. (1961) concluded that the processing method employed does affect the nutritive value of the product. A sample of feather meal containing 64% pepsin-digestible protein was inferior to other samples containing 70 to 83% pepsin-digestible protein when fed to chicks as the sole source of protein.

Xanthine Dehydrogenase

The xanthine dehydrogenase activity of avian organs is influenced by a variety of dietary changes and it is considered an adaptive enzyme (Stripe and Corte 1965, Scholz and Featherston 1968). Scholz and Featherston (1968) showed that the total amount of xanthine dehydrogenase available to the chick significantly decreases when a protein-free diet is fed for a 24-hour period. However, in contrast to this, they found that in chicks starved 24 hours the xanthine dehydrogenase level remained the same as chicks fed ad libitum. Stripe and Corte (1965) similarly observed an increase in xanthine dehydrogenase activity (on the basis of nitrogen content) in the kidney of starved pigeons. Scholz and Featherston (1968) fed a diet containing 25% isolated soybean protein to one-day-old chicks for the first 10 days. From this time, one-half of the chicks were fed a diet containing 75% isolated soybean protein and one-half were continued with the 25% diet. The protein content of the 25% and 75% isolated soybean protein diets was 21.0% and 63.9%, respectively.

Their findings showed birds fed the high protein diet had significantly higher xanthine dehydrogenase levels when compared with birds fed the 25% isolated soybean protein diet. These results were observed, regardless of the basis of expressing the enzyme's activity (units/g. liver, units/100gm. liver N, units/liver or units/100g. body wt.). Remy and Westerfield (1951) had also shown that low-protein diets depleted the liver of xanthine dehydrogenase. Westerfeld et al. (1962) showed a linear increase in liver xanthine dehydrogenase activity in chicks and poults when protein

intake was increased.

Since xanthine dehydrogenase has been shown to be an adaptable enzyme, (Stripe and Corte 1965, Scholz and Featherston 1968) it would seem feasible this enzyme may also be affected by the quality of the protein taken in by the bird. The results of Kazemi-Shirazi (1972) with laying hens showed that this enzyme was probably a reflection of the protein quality as well as quantity. He fed diammonium citrate, urea and soybean meal as protein sources. He found that birds consuming the soybean meal protein had the highest enzyme activity whereas, birds fed the two non-protein nitrogen sources had considerably lower hepatic enzyme activity.

Net Protein Values

Nutritive evaluation of proteins in the avian species presents more problems and, as a result, involves greater difficulty in carrying out the classical Biological Value studies because of urine and feces being excreted jointly. To perform surgery and modify the bird does not yield practical results nor can it easily be adapted to large-scale routine testing of various protein sources.

Since Bender and Miller (1953) developed the carcass retention method for growing rats, this suggested to Summers and Fisher (1961) that net protein values could also be obtained from chickens without recourse to surgery or chemical separation of excreta. Forbes and Yohe (1955) showed a good correlation between the carcass retention method and the classical balance technique in the rat. De Muelenaere et al. (1960) have shown the

carcass analysis method for determining net protein utilization can be applied successfully to chicks.

Summers and Fisher (1961) have developed an assay procedure for determining net protein values. They have also shown the usefulness and relative consistency of the water:nitrogen (W:N) ratio both within and between experiments. Utilization of the W:N ratio method considerably decreases the laboratory analysis of carcasses for nitrogen. This method has been shown by Summers and Fisher (1961) to be consistent and reliable.

Fisher et al. (1962) found the net protein values of feather meal to be 26.3% and that of a corn-soya diet to be 56.1%. Neither of these diets were supplemented with amino acids.

CHEMICAL DETERMINATIONS

Protein Retention

Feed and feces were prepared for chromium analysis according to the procedure outlined by Ewan[1]. Feed and feces were dried and kept in desiccators before all determinations. Approximately one-half gram of feed or one gram of feces was weighed accurately on a filter paper. The filter paper and contents were then placed in a 100 ml Kjeldahl flask with 3 glass beads and 15 ml of concentrated nitric acid. The samples were allowed to stand overnight and then boiled until about one-half of the nitric acid had distilled off. After cooling the sample for 10 minutes, 8 ml of concentrated perchloric acid was added. The remaining nitric acid was then evaporated and after the last nitric acid was distilled off, we continued heating the sample for 30 minutes. When the last of the nitric acid leaves, the digest becomes clear and white fumes are given off by the rapid oxidation. After cooling for 10 minutes, 3 ml of 5N hydrochloric acid was added and heating was resumed. After the hydrochloric acid and water were driven off and white fumes condensed in the neck of the flask, heating was continued for 10 additional minutes. After cooling, the sample was transferred quantitatively to a 100 ml volumetric flask. The sample was brought to volume by adding distilled water. The amount of chromium in samples was assayed by an atomic absorption procedure.

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[1]Ewan, R. C., 337 Kildee Hall, Iowa State University, Ames, Iowa. Determination of minerals in feeds. Personal Communication, 1972.

Nitrogen was assayed in dried excreta by the micro-Kjeldahl technique, while nitrogen in the feed was assayed by the standard macro-Kjeldahl method. Gram of nitrogen gained per gram of diet was calculated by using the following equation:

$$\text{g. N gained/g. diet} = \text{g. N/g. diet} - \frac{(\text{g. N/g. excreta})\ (\text{mg. } Cr_2O_3\text{/g. diet})}{\text{mg. } Cr_2O_3\text{/g. excreta}}$$

Liver Xanthine Dehydrogenase Activity

Xanthine dehydrogenase activity in the liver was determined as described by Strittmatter (1965). Livers were removed, blotted, weighed and frozen in liquid nitrogen. The livers were then placed in tissue sample bags and placed in a walk-in freezer at -32° C. All enzyme assays were carried out on these quick-frozen livers before seven days of storage were exceeded as recommended by Strittmatter (1965). Approximately 3.0 to 3.5 grams of quick-frozen liver was weighed accurately and then diluted with 9 volumes of ice-cold buffer A. The liver samples were homogenized in a Potter-Elvehjem homogenizer for 60 seconds using 14-15 strokes. The homogenate was then centrifuged at 11,000 rpm for 30 minutes in a refrigerated centrifuge (0° C.). One tenth ml of the supernatant was withdrawn by pipette and used for sample reading. Xanthine dehydrogenase activity was assayed by measuring the increase in absorbency at 290 mμ as uric acid was formed in 0.03 M phosphate buffer, pH 7.5, with 2.7×10^{-3} M xanthine as substrate and 6.7×10^{-4} M NAD as the electron acceptor. Activities were calculated from a period of linear absorbency change,

usually 3 to 7 minutes after addition of enzyme. Absorbency change was also recorded in control cuvettes as above with 0.1 ml buffer B replacing 0.1 ml supernatant. Xanthine dehydrogenase was calculated using the following equation:

$$\text{Uric acid formed/g. tissue/min} = \frac{\Delta E \cdot V \cdot DF}{10^{-6} \cdot \xi \cdot d \cdot v}$$

d = length of light path of cuvette, 1cm.

V = volume of solution in the cuvette, 3.00 ml.

v = volume of sample, 0.1 ml.

ΔE = change in absorbency/min.

DF = dilution factor, 10.

ξ = uric acid extinction coefficient, 11.5 X 10^6 cm^2 at 283 and pH 1.

Reagents:

1. Buffer A -0.5 M solution of potassium phosphate dibasic and potassium phosphate monobasic (pH 7.0). To one liter of the buffer 10 ml of 0.001 M EDTA was added.
2. Buffer B - 0.03 M solution of potassium phosphate dibasic and potassium phosphate monobasic (pH 7.5).
3. 0.0067 M NAD.
4. 2.7 X 10^{-3} xanthine.
5. Xanthine buffer - 30 ml of xanthine solution mixed with buffer B.

Amino Acid Analysis of Feather Meal

Feather meal samples were prepared for amino acid analysis according to the procedure outlined by Miller[2]. Approximately one-half gram of air-dry feather meal was weighed accurately. The feather meal was transferred quantitatively into a 30 ml screw cap culture tube. Twenty five ml of 6N HCl, which also contained 10 μM/ml of the internal standard norleucine, was added to the culture tube. The contents of the culture tube were then flushed with nitrogen to reduce oxidation as much as possible. Contents of the tube were mixed thoroughly and placed in an oven at 105° for 24 hours. Upon removal from the oven, the contents were mixed thoroughly and filtered with a Buchner funnel. One ml aliquot of the filtered hydrolysate was diluted with a hydrolysate sample buffer and the pH adjusted to 2.0. The hydrolysate was transferred to a 100 ml volumetric flask and brought to volume with sample buffer. One-half ml of this solution was then used for amino acid analysis by placing in the sample cartridge. Amino acids were assayed by a Technicon Auto Analyzer.

Available Lysine

Feather meal samples were prepared for available lysine analysis according to Kakade and Liener (1969) modified by Zimmerman and Lewis[3].

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[2]Miller, D. L., Valmac Industries, Box 847, Russellville, Arkansas 72801. Acid hydrolysis of amino acids in feedstuffs. Personal Communication, 1970.

[3]Zimmerman, D. and Lewis, A., 337 Kildee, Iowa State University, Ames, Iowa. Available Lysine - Trinitrobenzenesulfonic acid. Personal Communication, 1972.

Approximately 20 mg of air dry feather meal was weighed accurately. The feather meal was quantitatively transferred into a 20 ml culture tube and covered with an inverted glass vial. One ml of 4% sodium bicarbonate was added to each sample tube. Sample blanks were also weighed into culture tubes and 3 ml of 6N HCl followed by 1 ml of 4% sodium bicarbonate were added to the sample blank tubes. The sample blanks were prepared because there is some background color inherent in the reaction; therefore, the O. D. of the sample blanks were subtracted from the appropriate O. D. of the samples. Standards and standard water blanks were prepared using ξ-TNP-Lysine and water, respectively. One ml of the standards and 1 ml of water were added to 20 ml culture tubes and mixed with 1 ml of 0.1% TNBS. All tubes were heated in a water bath at 40° C. for 10 minutes with shaking. There was continued heating and shaking at 40° C. for 2 hours after 1 ml of 1% TNBS was added to samples and sample blanks. After cooling, 3 ml of 6N HCl was added to samples and the standards but not to the sample blanks. The reaction mixture was then autoclaved at 120° C. for 1 hour. Exactly 5 ml of water was added to each tube after cooling. Samples and sample blanks were filtered into 200 X 25 mm boiling tubes and extracted twice with 10 ml of ethylether by spinning for exactly 30 seconds on a vortex.

All tubes were then heated in a hot water bath (70° C.) for 10-15 minutes to eliminate dissolved ether. Upon cooling 1 ml of the sample and sample blanks were transferred to a 10 ml volumetric flask and diluted to volume with water. The standards were not diluted as were the above samples.

Optical density was read at 346 mμ. Five replications were determined for each feather meal sample.

Reagents:

1. 4% Sodium bicarbonate solution.
2. 6N HCl.
3. 0.1% and a 1.0% TNBS solution.
4. Stock standard solution containing 1.0 mg ξ-TNP-Lysine/ml.

Net Protein Value

Net protein value for the five feather meals and a corn-soybean combination were determined following a procedure outlined by Summers and Fisher (1961). The chicks were fed the experimental ration containing about 13% of the feather meal protein for 2 weeks, at the end of which time the birds were starved for 12 hours. The chicks were then weighed, killed with chloroform and dried to constant weight in a forced-air oven at 80° C. Moisture values were obtained by the difference between the final live weight of the chicks and their dried weight. One chick from each pen (i.e. 4 chicks per treatment) was selected at random, ground, mixed well in a Waring Blender and stored in a desiccator at -32° C. These carcasses were sampled for macro-Kjeldahl analysis, which was carried out in duplicate. One to one and a half grams of carcass were used for each nitrogen determination. The carcasses were analyzed for nitrogen within 5 days after they were stored.

Water:Nitrogen ratios were calculated for one bird per pen and carcass nitrogen values estimated for the 4 remaining birds in the same pen from this W:N ratio.

Net protein values were calculated by the following equation as defined by Bender and Miller (1953):

$$NPV = \frac{B_f - B_k + I_k}{I_f}$$

where B_f and I_f denote carcass nitrogen and nitrogen intake, respectively, of animals fed the test diet, and B_k and I_k equal carcass nitrogen and nitrogen intake with the nitrogen-free diet, respectively.

Pepsin Digestibility

Feather meal samples were prepared for pepsin digestibility analysis according to Gehrt et al. (1955). The method was modified and adapted for use in this laboratory. One gram of the feather meal sample was placed in a 15 ml centrifuge tube, and to this 10 ml of diethyl ether was added. The sample was allowed to stand for 10 minutes with frequent agitation and then centrifuged for 5 minutes at 3000 r.p.m. The clear supernatant liquid was poured off and the extraction was repeated with four 5 ml portions of ether, stirring and centrifuging each time and pouring off all extracts. The residue was saved for the defatted sample.

The defatted samples were air dried in centrifuge tubes until free from ether odor and 10 ml of carbon tetrachloride (purified or N.F. grade) was added. Samples were agitated until completely suspended and centrifuged 5 minutes. The upper layer was poured into a dry 125 ml Erlenmeyer

flask and the separation was repeated with another 10 ml of carbon tetrachloride, again adding the upper layer to the Erlenmeyer flask. The light fraction was saved for the next step.

Solvent was evaporated from the light fraction in a warm (60° to 70°C) water bath until the residue was free of solvent odor and the samples were allowed to air dry over night under a ventilation hood. A freshly prepared (50 ml), prewarmed (42° to 45°C) solution of 0.1 N HCl containing 0.1 gram of pepsin (1:10,000) was added, the flask stoppered and incubated at 40°C for 40 to 48 hours. At least once every 12 hours the samples were agitated by swirling the flask. The samples were transferred quantitatively to a tube and centrifuged 5 minutes. The residue was decanted and washed twice with warm water and once with denatured alcohol and then poured off and drained. Five to 10 ml of alcohol was added, the sample filtered quantitatively in a Buchner funnel and washed with alcohol and dried. The residue and filter paper were transferred to a 50 ml beaker, dried in the oven 30 minutes at 100° to 110°C and the residue was then brushed from the filter paper onto a watch glass and weighed. Protein content of this residue was determined by the micro-Kjeldahl method. This residue is the pepsin-indigestible portion of the light fraction.

Percent feather meal protein digested by pepsin was calculated using the following equation:

(R) (PI) = indigestible protein

P - indigestible protein = digestible protein

$$\frac{\text{digestible protein}}{P} \times 100 = \text{pepsin digestible protein}$$

R = pepsin-indigestible residue

PI = protein content of pepsin-indigestible residue

P = total protein in original sample.

Feather Meal Analysis

The chemical procedures performed on the 5 differently processed feather meals are described in the previous sections. Results of these analyses are listed in Table 1.

Table 1. Chemical analysis of the 5 differently processed feather meals

Amino acids (% of Protein)	Feather Meals A	B	C	D	E
Arginine	8.02	4.62	4.38	7.47	8.78
Glycine	6.62	5.45	5.46	7.01	9.02
Histidine	0.64	0.43	0.59	0.74	(lost)
Isoleucine	5.03	3.50	4.55	5.21	6.22
Leucine	11.94	6.94	8.59	8.95	9.47
Lysine	1.65	1.18	1.78	2.36	(lost)
Methionine	0.36	0.34	0.34	0.55	0.44
Phenylalanine	5.80	4.22	7.85	5.80	5.39
Threonine	2.08	1.71	2.49	2.21	2.24
Valine	8.33	6.75	10.43	7.95	7.31
Aspartic Acid	5.49	5.78	5.31	5.60	5.88
Serine	8.27	8.96	7.86	8.69	9.23
Glutamic Acid	7.05	6.13	8.87	8.29	7.27
Proline	9.04	8.56	9.52	14.74	9.73
Alanine	4.01	2.64	2.23	3.20	3.14
Cystine[c]	3.38	2.09	3.68	1.55	2.15
Tyrosine	2.99	3.21	3.23	3.10	2.93
Protein, % (Kjeldahl)	84.7 [a]	83.4	83.1	82.9	83.1
Ether Extract, %	2.3 [a]	1.4	2.5	1.2	2.4
Ash, %	4.0 [a]	3.6	4.2	3.8	3.6
Available Lysine (% of Prot.)	1.21[b]	0.79	1.40	1.59	1.42
Pepsin digestible, %	71.8 [a]	74.6	73.8	74.2	72.9

[a]Mean of 3 determinations.

[b]Mean of 5 determinations.

[c]Cystine values probably low because of extent of hydrolysis prior to analysis. Tryptophan was not determined.

In general, the amino acid analysis does not follow any set pattern that can be related to the processing method. However, cystine illustrates that increased processing time and pressure does decrease the cystine content as a percentage of the protein in feather meal. There does not appear to be an increased destruction of methionine or lysine when feathers are processed under more strenuous conditions. Feather meal D contains the greatest amount of lysine, methionine and histidine of the five feather meals. These amino acids are known to be three of the four most limiting amino acids in feather meal (Moran et al. 1966). Feather meal D also has the most available lysine expressed as a percentage of its protein, and the greatest total free amino acid content when all the amino acids are totaled within a feather meal.

The differences between the feather meals with respect to their pepsin digestibility are not of great enough magnitude to warrant solid conclusions from these data alone. However, there is a definite trend for the feather meals which have undergone the more severe processing to have slightly higher pepsin digestibility values. Feather meal E had the lowest pepsin digestibility value except for feather meal A, which was processed under the mildest conditions of the "new" processes.

The processing method also had an effect on the percentage of crude fat. Feather meals processed for 60 minutes had a marked decrease in their fat content when compared to the 30 minutes time of processing. Protein content (Kjeldahl) was slightly decreased by increased time and pressure

of the processing, but this was probably non-protein nitrogen that was driven off, or the result of the decreased cystine content under these conditions.

EXPERIMENTAL PROCEDURE

General Management and Data Collection

Seven-day-old Welp broiler cockerels were used in all experiments. They were fed a commerical starter diet during the pre-experimental period. Birds were confined in 5-deck batteries equipped with wire floors, and thermostatically controlled, throughout the pre-experimental and experimental periods. The heat was adjusted each week to meet the birds requirement. Feed and water were consumed ad libitum in all trials. Biological response was measured by weight gains and feed conversion values in Experiments I, II, III, IV, V and VI. Other parameters, to be described later, were measured in Experiments VII and VIII. Complete randomization of experimental material and treatments was used in all trials, except for the initial pen weights which were restricted to the extent of controlling the weight range within arbitrary limits so as to reduce variation within pens and between replicates as much as possible. Analysis of variance tests, which included planned comparisons, were made on the experimental data according to Snedecor and Cochran (1967).

Objective

The overall objective of the eight experiments performed was to evaluate five feather meals, processed by the following procedure:

Description	PSI	Minutes	Agitation
Feather meal A	40	30	Intermittent
Feather meal B	40	60	Intermittent
Feather meal C	50	30	Intermittent
Feather meal D	50	60	Intermittent
Feather meal E (std. process)	35	30	Constant

Experiment I

Experimental design

Ten seven-day-old Welp cockerels were allotted to each of 15 pens. Three replicate groups were fed each of the 5 experimental rations. One experimental ration consisted of a simple corn-soybean meal basal diet, whereas the other four experimental rations consisted of feather meals A, B, C, or D, which replaced all of the soybean meal in the basal diet. Table 2 lists the ingredients in the diets. All feather meal diets (A, B, C, D) contained 18% feather meal. Diets were maintained isocaloric and isonitrogenous, with no supplementation of amino acids. Group weights and feed consumed were recorded after the chicks had been on the experimental diets 14 days, at which time the experiment was terminated.

Objective

The objective of this experiment was to place extreme stress on the chicks and to determine if the new processing methods would result in a marked response different from any other process. The "standard" processed feather meal E was not included in this experiment due to a delay in its shipment.

Results and discussion

All diets containing feather meal resulted in significantly inferior weight gains and feed conversion values when compared to the results from the corn-soybean meal diets. Appendix Table 1 gives a more detailed

Table 2. Composition of rations - Experiment I

Ingredient	Basal (%)	Feather meal A,B,C,D (%)
Ground yellow corn	59.00	76.75
Soybean meal (48%)	34.00	-
Feather meal	-	18.00
Dicalcium phosphate	1.50	1.75
Ground limestone	1.50	1.50
Salt + mineral mix[a]	0.50	0.50
Vitamin mix[b]	0.50	0.50
Soybean oil	3.00	1.00
Calculated analysis:		
M.E., kcal./g.	3.15	3.15
Calcium, %	0.95	0.95
Phosphorous, %	0.64	0.66
Protein, % (Kjeldahl)	21.8	21.9

[a]Supplied per kilogram of diet: NaCl, 4.5 g.; Mn, 88 mg.; Fe, 14 mg.; Cu, 2.2 mg., I_2, 1.2 mg.; Co, 0.14 mg.; Zn, 19 mg.

[b]Supplied per kilogram of diet: vitamin A, 7500 I.U.; vitamin D_3, 1000 I.C.U.; menadione, 1 mg.; vitamin B_{12}, 10 mcg.; riboflavin, 5 mg.; pantothenic acid, 10 mg.; niacin, 25 mg.; choline, 450 mg.; methionine equivalent, 1000 mg.; Santoquin, 125 mg.; penicillin, 8.25 mg.; streptomycin, 16.5 mg.

analysis of variance of weight gains and feed conversion values. The decreased response was to be expected since feather meal is known to be deficient in several amino acids required by the chick. When feather meal replaced all of the soybean meal protein in the basal diet, feed consumption was greatly decreased. Chicks consumed the corn-soybean meal diet

on the average of 1011 grams per bird, whereas chicks fed the feather meal diets consumed an average of 364 grams of feed per bird for the 14-day period. This vividly shows how a diet containing a large percentage of feather meal decreases the palatability of the diet.

One of the four feather meals tested, feather meal D (50 psi for 60 min.) tended to produce the greater gains and feed conversion than the other feather meals. These differences, however, were not statistically significant. Table 3 contains more detailed data on weight gains and feed conversion values.

Table 3. Effect of feather meal process on weight gains to 3 weeks of age and feed conversion - Experiment I

Diet	Weight gain/bird	Feed/gain
Corn-soybean	468 ± 6.99[a]	1.80 ± 1.07
Feather meal A	113	8.18
Feather meal B	103	10.41
Feather meal C	90	8.74
Feather meal D	124	7.77

[a]All values represent means of 3 replicate groups ± their standard errors.

Chicks receiving feather meal D averaged 11 grams per bird greater weight gains when compared with the next closest competitor (feather meal A). Birds fed feather meal D averaged 21 grams and 34 grams per bird greater weight gains than feather meal B or feather meal C, respectively. Even though these differences were not statistically significant, the results tend to indicate that the feather meal that undergoes the more

intense processing procedure may have more of its amino acids made available to the chick.

Since the "standard" processed feather meal E was not included in this experiment, it was not possible to evaluate the intermittent and constant agitation mode of mixing the feather meals during processing.

Experiment II

Experimental design

Ten seven-day-old Welp cockerels were allotted to each of 33 pens. Three replicate groups were fed each of the 11 experimental rations. Experimental rations consisted of a simple corn-soybean basal ration and the five differently processed feather meals (A, B, C, D, E). Each feather meal provided 2.5 or 5%, of the dietary protein substituting for soybean meal protein. All diets were maintained isocaloric and isonitrogenous, with no supplementation of amino acids. Composition of the diets is shown in Table 4.

Group weights and feed consumption were recorded after the chicks had been on the experimental diets for 14 and 28 days, at which time the experiment was terminated.

Objectives

The objective of this experiment was to determine the effect of new processing methods of feathers upon growth response and feed conversion of chicks when feather meals were supplemented at the practical levels of 2.5 and 5% of the dietary protein. Another objective in this experiment

was to compare the new processing methods with the "standard" processing method.

Table 4. Composition of rations - Experiment II

Ingredient	Basal (%)	Protein from feather meal 2.5% (%)	Protein from feather meal 5% (%)
Ground yellow corn	60.50	63.00	65.60
Soybean meal (48%)	34.00	28.70	23.00
Feather meal	-	variable[b]	variable[b]
Dicalcium phosphate	1.50	1.90	1.90
Ground limestone	1.50	1.50	1.50
Salt + mineral mix[a]	0.50	0.50	0.50
Vitamin mix[a]	0.50	0.50	0.50
Soybean oil	1.50	1.00	1.00
Calculated analysis:			
M.E., kcal./g.	3.07	3.04	3.06
Calcium, %	0.95	1.02	1.01
Phosphorous, %	0.64	0.71	0.71
Protein, % (Kjeldahl)	21.8	21.9	21.9

[a]See footnotes a and b, Table 2, page 26.

[b]The exact amount of feather meal used varied with respect to individual protein content, see Table 1, page 21.

Results and discussion

Feather meals from the four experimental processing methods (A, B, C, D) supported growth comparable to the basal diet up to five weeks of age. There was no significant difference statistically between the levels of

2.5 and 5% of feather meal protein, although the 5% tended to decrease growth slightly (Figure 1).

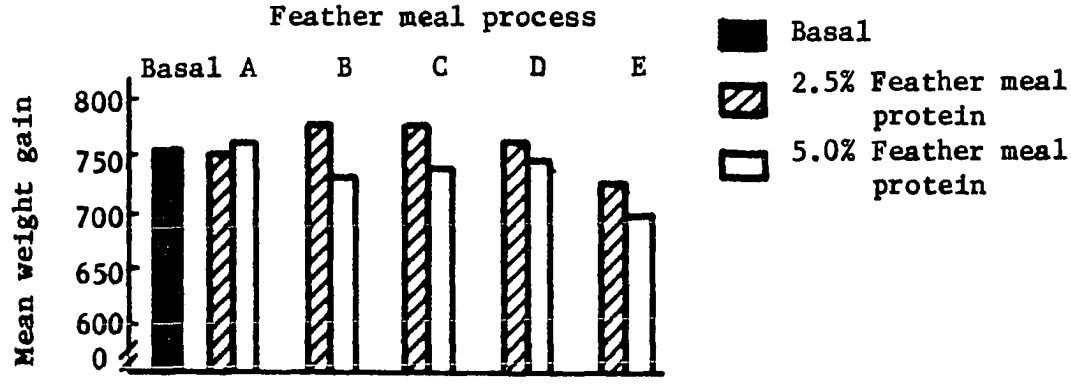


Figure 1. Effect of feather meal process and feather meal protein level on chick weight gain to 5 weeks of age

Feather meal E ("standard" processing method) did not support growth equivalent to the other feather meal diets at either the 2.5 or the 5% protein levels. The decreased weight gain produced by feather meal E was significant ($P < 0.05$). Feed conversion was not significantly different among groups fed the five feather meal diets or between feather meal diets and corn-soybean meal diets. Feather meal level, likewise, did not affect feed conversion significantly. Appendix Table 2 gives a more detailed analysis of variance of weight gains and feed conversion values.

The data in Table 5 indicate that further processing than is considered standard today may be needed. In comparing feather meal E to all other feather meals, it could also be said that intermittent agitation may be more beneficial than the standard constant agitation method.

Table 5. Mean weight gains to 5 weeks of age and feed conversion ( ) - Experiment II

Diet	Feather meal protein level		Mean
	2.5%	5%	
Basal	759 ± 20[a] (2.03) ± 0.11		
Feather meal A	751 (1.85)	751 (2.08)	751 (1.97)
Feather meal B	765 (1.95)	723 (2.09)	744 (2.02)
Feather meal C	761 (1.90)	734 (1.95)	747 (1.92)
Feather meal D	748 (2.04)	735 (1.86)	742 (1.95)
Feather meal E	724 (2.03)	700 (1.96)	712 (2.00)
Mean	750 (1.95)	729 (1.99)	

[a]All values represent means of 3 replicate groups ± their standard errors.

Experiment III

Experimental design

Ten seven-day-old Welp cockerels were allotted to each of 40 pens. Two replicate groups were fed each of the 20 experimental rations. Experimental rations consisted of four dietary protein levels (22, 20, 18 16%), with protein provided from corn-soybean meal; or corn-soybean meal-feather meal. Table 6 lists the composition of the basal diets for this experiment and for Experiments IV and V. Feather meal A (40 psi for 30 min.) and feather meal B (40 psi for 60 min.) provided protein at 5 or 7.5%, substituting for soybean meal protein. Diets were made isocaloric and isonitrogenous by adjustment of corn, soybean oil and alphacel. Lysine and methionine were added to bring all diets up to NRC (1966) standards for these amino acids. Group weights and feed consumption were recorded indentically as in Experiment II.

Table 6. Composition of basal rations - Experiments III, IV and V

Ingredient	Basal-22 (%)	Basal-20 (%)	Basal-18 (%)	Basal-16 (%)
Ground yellow corn	60.44	65.42	69.09	72.46
Soybean meal (48%)	34.00	29.10	24.00	19.30
Soybean oil	1.50	1.00	1.00	1.00
Cellulose	-	-	1.00	2.00
Dicalcium phosphate	1.50	1.90	1.90	1.90
Ground limestone	1.50	1.50	1.50	1.50
Salt & mineral mix[a]	0.50	0.50	0.50	0.50
Vitamin mix[a]	0.50	0.50	0.50	0.50
Methionine hydroxy analogue	0.06	0.08	0.11	0.14
Lyamine-50	-	-	0.40	0.70
Calculated analysis:				
M.E., kcal./g.	3.07	3.07	3.07	3.06
Calcium, %	0.95	1.01	1.00	0.99
Phosphorous, %	0.64	0.70	0.68	0.66
Protein, % (Kjeldahl)	21.6	19.0	17.6	15.5

[a]See footnotes a and b, Table 2, page 26.

Objective

The objectives of this experiment were to compare the effects two time periods of heating (30 min. vs 60 min.) at 40 psi have upon chick growth rate and feed conversion. A wide dietary protein range was used to determine what effect these feather meals have in a diet adequate in protein and the effect they have in a diet suboptimal in protein. Sibbald *et al.* (1962) and Tsang *et al.* (1963) have shown that feather meal can replace much more of the dietary protein when the protein level is adequate (22-20%) as compared with a low protein level (16-18%). It would also seem feasible that a poorer quality feather meal might be detected more easily in the lower protein diets.

Results and discussion

The results of this experiment showed no significant difference between feather meals A and B with respect to weight gain. There was a significant difference at the 0.05 level of probability between feed conversion values, with feather meal A being used most efficiently (Table 7).

The mean weight gains produced by the basal diet were significantly greater than those produced by the feather meal diets when averaged over the two feather meal levels (5 and 7.5%) and the two feather meals A and B. This same comparison was not statistically significant with respect to feed conversion values. Feather meal A at the 5 and 7.5% level produced lower weight gains than those produced by the basal diet at all dietary protein levels except when added at the 5% level in the 16% protein diet (Table 7). Feather meal B, when supplying 5% protein in the 22, 20 and 16% protein diets gave equivalent results to those produced by the basal diets. When the protein level was suboptimal (18 and 16%), chicks fed diets containing 7.5% feather meal protein did not grow as well, nor was feed conversion as efficient, as when birds consumed the basal ration or the ration containing 5% feather meal protein (Table 7).

Table 7 illustrates that feather meal A and B resulted in lower weight gains and poorer feed efficiency when fed the 7.5% feather meal protein level as opposed to the 5% feather meal protein level. These differences were statistically significant ($P < .01$).

Although the difference between the chicks' growth responses obtained from feather meals A and B was not significant, there appears to be a

Table 7. Effect of dietary protein level, feather meal type and feather meal level on weight gains to 5 weeks of age and feed conversion ( ) - Experiment III

Diet	Dietary protein (%)				
	22	20	18	16	Mean
Basal	746[a](1.92)[b]	736 (1.96)	711 (1.95)	530 (2.10)	681 (1.98)
F.M. A - 5.0% prot.	667 (1.95)	704 (1.86)	669 (2.00)	575 (2.27)	654 (2.02)
F.M. A - 7.5% prot.	678 (1.97)	676 (1.97)	550 (2.11)	321 (2.84)	556 (2.22)
F.M. B - 5.0% prot.	721 (1.91)	730 (1.94)	670 (2.03)	551 (2.29)	668 (2.04)
F.M. B - 7.5% prot.	700 (1.91)	654 (1.97)	598 (2.24)	253 (3.14)	551 (2.32)
Means					
F.M. A (5 & 7.5%)	672 (1.96)	690 (1.91)	609 (2.05)	448 (2.55)	605 (2.12)
F.M. B (5 & 7.5%)	711 (1.91)	692 (1.95)	634 (2.13)	402 (2.71)	610 (2.17)
F.M. A & B (5.0%)	694 (1.93)	717 (1.90)	670 (2.01)	563 (2.28)	661 (2.03)
F.M. A & B (7.5%)	689 (1.94)	665 (1.97)	574 (2.17)	287 (2.99)	554 (2.27)

[a]All values represent means of 2 replicate groups ± their standard error of 40.

[b]All values represent means of 2 replicate groups ± their standard error of 0.05.

tendency for the feather meal processed for the longer period of time (feather meal B) to produce slightly better weight gains (Table 7). However, except for the 22% dietary protein level, feather meal B resulted in significantly poorer feed conversion than did feather meal A (Table 7). This difference was significant at the 0.05 level of probablity. The difference in feed consumption between diets containing feather meals A and B was not significant.

Table 7 also depicts the significant ($P < .01$) linear and quadratic effects produced by the dietary protein levels for weight gains and feed conversion values.

Table 7 illustrates the significant linear protein level X feather meal level interaction. Within feather meals A and B, the fastest rate of gain and best feed conversion were obtained from the 20% protein diets when the feather meals were added at the 5% protein level. The greatest rate of gain and best feed conversion when the feather meals were added at the 7.5% protein level were obtained with the 22% protein diets. This is another indication that the more feather meal protein one substitutes into the diet, the higher that diet must be in total dietary protein.

The linear protein level X feather meal level X feather meal type interaction was significant for weight gains ($P < .01$) and feed efficiency ($P < .05$). This three way interaction indicates that the linear protein level X feather meal level interaction is dependent upon the type of feather meal. Therefore, when examining the linear protein effect one must consider the level at which the feather meal was added and the type

of feather meal. More detailed data on feed efficiency values and weight gains are listed in Table 7.

It is also evident from Table 7 that the trend for feather meal B to produce slightly better growth is reversed at the 16% dietary protein level. Since feather meal A was not processed for as long a period of time as feather meal B, one might postulate that feather meal A did not have as great a percentage of its amino acids made available to the chick. Poorer quality feather meal might be expected to give inferior results in the 16% protein diet; however, feather meal A produced better weight gains and feed efficiency values than those produced by feather meal B at this protein level. This relatively good response to feather meal A at this suboptimal protein level leaves a quandary and cannot be explained on the basis of the results of this experiment.

Table 7 shows that the 20% protein diet resulted in the greatest rate of gain and best feed efficiency for feather meal A, whereas the 22% protein diet gave the best results for feather meal B. This was significant at the 0.01 level of probability for feed conversion values, but was not significant with respect to weight gains. These data account for the significant linear protein level X feather meal type interaction when considering feed conversion values.

A significant feather meal type X feather meal level interaction was also observed with respect to feed conversion values. This is substantiated by the fact that when one increases the feather meal protein from 5 to 7.5% of the dietary protein with feather meal A there is an average increase in feed required per gram of gain of 0.20 g. Whereas, if feather

meal B is used to increase the level from 5 to 7.5%, feed required per gram of gain is increased an average of 0.28 g. This difference is significant at the 0.01 level of probability.

The linear protein level X basal vs. feather meals interaction was significant with respect to feed conversion values ($P < .05$). This is explained by the fact that the linear protein trend in the basal diet is not the same as it is in the feather meal diets (Table 7). As protein was reduced from 22 to 16%, feed required per gram of gain was increased by 9.4% when chicks were fed the corn-soybean meal diet, but was increased by 35.9% when diets contained feather meal. Most of this increased feed requirement was accounted for by the 7.5% protein feather meal diet, but even when feather meals added only 5% protein, feed required per gram of gain was increased by 18.1% as dietary protein was decreased from 22 to 16%. A complete summary of the analysis of variance of weight gain data and feed conversion values is presented in Appendix Table 3.

It appears from these data that, when feather meal B is used to supply not more than 5% of the dietary protein in sufficiently high protein diets (22 and 20%), this feather meal has amino acid availability of a high order. It is also noted that when feather meal protein makes up approximately 50% or more of the dietary protein, acceptability of the diet is greatly decreased. Groups fed the 16% protein diet containing 7.5% feather meal protein consumed an average of only 30 g. of feed per bird per day, while the groups fed the 16% protein diet with 5% feather meal protein consumed an average of 46 g. of feed per bird per day. The birds fed the 16% protein basal diet consumed 40 g. of feed per bird per day.

Feed efficiency data also resulted in other significant sources of variation. This variation is contained in the residual of the analysis of variance table (Appendix Table 3). Upon examining the data, cubic effects can be observed. The cubic effect with its various interactions, as well as quadratic interactions, do not possess meaningful information in an experiment of the type. Consequently, these interactions were not examined individually.

Experiment IV

Experimental design

The experimental design is identical to that used in Experiment III. In Experiment IV feather meal C (50 psi for 30 min.) and feather meal D (50 psi for 60 min.) provided protein at 5 or 7.5% of the ration, substituting for soybean meal protein. The basal diets in this experiment were the same as those listed in Table 6, Experiment III.

Objectives

In this experiment we compared the effect time of processing (30 min. vs. 60 min.) at 50 psi had on the biological response of chicks, as measured by weight gains and feed conversion. Other objectives of this experiment were the same as those listed for Experiment III.

Results and discussion

The results of this experiment (Table 8) show that feather meal D produced significantly better weight gains ($P < .05$) and better feed

conversion ($P < .01$) than resulted when feather meal C was included in the ration. However, at the 22% dietary protein level, the growth responses were about equal and feather meal C was more efficiently used than feather meal D.

Table 8 also depicts the significant ($P < .01$) linear and quadratic effects resulting from the dietary protein levels for weight gains and feed conversion values. The abrupt reduction in gains and feed efficiency at the 16% dietary protein level results in the quadratic effect.

As in Experiment III, there was a significant ($P < .01$) feather meal type X feather meal level interaction with respect to feed conversion values. This is explained by the fact that when feather meal C protein in the diet was increased from 5 to 7.5%, there was an average increase in feed required per gram of gain of 0.66 g. Whereas, when feather meal D protein was increased from 5 to 7.5%, feed required per gram of gain was increased an average of only 0.36 g.

The basal diet resulted in significantly greater weight gains ($P < .01$) and better feed efficiency ($P < .01$) than both feather meal diets when averaged over the 5 and 7.5% levels of feather meal protein. Except for the 16% protein diets and the 18% protein diet where 7.5% feather meal protein was incorporated, feather meal D gave equivalent or better results than the basal diets. Feather meal C also produced equivalent or better results when added at the 5% level of protein in the 22, 20 and 18% protein diets. Therefore, it was the 7.5% feather meal protein level, especially with feather meal C, and the 16% protein diet that resulted in the significant difference between the basal diets and the

Table 8. Effect of dietary protein level, feather meal type and feather meal level on weight gains to 5 weeks of age and feed conversion ( ) - Experiment IV

Diet	Dietary protein (%)				Mean
	22	20	18	16	
Basal	669[a](2.06)[b]	673 (2.11)	644 (2.14)	615 (2.30)	650 (2.13)
F.M. C-5.0% prot.	651 (2.06)	699 (2.07)	671 (2.03)	570 (2.49)	648 (2.16)
F.M. C-7.5% prot.	722 (2.04)	579 (2.24)	490 (2.41)	197 (4.58)	497 (2.82)
F.M. D-5.0% prot.	693 (2.02)	680 (2.04)	689 (2.09)	570 (2.26)	658 (2.10)
F.M. D-7.5% prot.	667 (2.25)	676 (2.15)	577 (2.21)	305 (3.23)	556 (2.46)
Means					
F.M. C (5 & 7.5%)	687 (2.05)	639 (2.15)	580 (2.22)	383 (3.53)	572 (2.49)
F.M. D (5 & 7.5%)	680 (2.13)	678 (2.10)	633 (2.15)	439 (2.74)	608 (2.28)
F.M. C & D (5.0%)	672 (2.04)	689 (2.05)	680 (2.06)	570 (2.37)	653 (2.13)
F.M. C & D (7.5%)	695 (2.15)	627 (2.20)	533 (2.31)	252 (3.90)	527 (2.64)

[a]All values represent means of 2 replicate groups ± their standard error of 31.

[b]All values represent means of 2 replicate groups ± their standard error of 0.09.

feather meal diets. The 7.5% feather meal protein level decreased weight gains and feed efficiency when compared to the 5% added feather meal protein level (Table 8). These differences were significant at the 0.01 level of probability. This is especially evident when considering the suboptimal protein levels.

The significant ($P < .01$) feather meal type X linear protein level interaction with respect to feed efficiency can be observed in Table 8. Here, the linear effect of the protein levels depends on which feather meal one is considering. As protein was reduced from 22 to 16%, feed required per gram of gain was increased by 28.8% when the chicks were fed feather meal D; whereas, when feather meal C was fed, the feed required per gram of gain increased by 72.1%.

Table 8 illustrates the significant ($P < .01$) linear protein level X feather meal level interaction. Considering feed conversion values, the 7.5% feather meal protein level decreased efficiency as diet protein was decreased much more than the 5% protein level. Only with the 16% protein diet did the 5% feather meal protein level greatly depress feed efficiency. This same trend was observed with weight gains. However, with respect to feed conversion, this effect was also dependent upon the feather meal type. This accounts for the three-way interaction of linear protein level X feather meal level X feather meal type being significant ($P < .01$). Upon examining data in Table 8, one finds that feed efficiency decreases much more rapidly as the dietary protein level decreases with the 7.5% feather meal protein diet with feather meal C (55.5%) than with feather meal D (29.5%). This is of importance, since it illustrates that the chicks

gained faster and maintained better feed efficiency with feather meal D regardless of the dietary protein level. Considering feed efficiency and weight gains, there was a significant ($P < .01$) linear protein level X basal vs. feather meal interaction. This is explained by the fact that the linear protein trend in the basal diet is not the same as it is in the feather meal diets. As dietary protein was reduced from 22 to 16%, feed required per gram of gain was increased by 11.6% and gains were reduced by 8.2% when chicks were fed the corn-soybean meal diets. However, when the diets contained feather meal, the feed required per gram of gain was increased by 51% and gain was reduced by 40.1% as the dietary protein was reduced from 22 to 16%. Most of this increased feed requirement and reduced gain was accounted for by the 7.5% protein feather meal diet, but even when feather meals added only 5% protein, feed required per gram of gain was increased by 13.7% and weight gains were reduced by 15.2% as the dietary protein was decreased from 22 to 16%.

This experiment supports previous observations that the further-processed feather meals do produce faster gains and possibly better feed efficiency. It appears from these data that feather meal D could supply 7.5% of the protein in a 22 or 20% protein diet. However, this would result in a significant decrease in feed efficiency. If prices were right and feather meal priced low enough, it could still possibly be profitable to use 7.5% feather meal D and accept the decrease in feed efficiency. This could be especially true in an integrated operation, where frequently they have their own facilities for processing feathers.

Considering both feather meals when fed at the 5% protein level in the 22, 20 and 18% protein diets, it appears that some growth stimulant may be present in the feather meal diets that is not present in the corn-soybean meal diets.

The fact that very high percentages of feather meal protein in the diets decrease acceptability of the ration, as shown in Experiments I and III, was also true in this experiment.

Again, it is quite evident that when feather meal replaces almost one-half of the dietary protein, as it does in the 16% protein diet when fed at the 7.5% feather meal protein level, growth and feed efficiency is greatly suppressed.

Feed efficiency data also demonstrated other significant sources of variation. This variation is contained in the residual of the analysis of variance table (Appendix Table 4). Upon examining the data, cubic effects can be observed. This cubic effect with its various interactions, as well as quadratic interactions, does not possess meaningful information in an experiment of this type. Consequently, these interactions were not examined individually. A detailed summary of the analysis of variance of feed conversion values and weight gain data is listed in Appendix Table 4.

Experiment V

Experimental design

In Experiment V only the "standard" processed feather meal E (35 psi for 30 min.) was compared with a basal corn-soybean meal diet. The design

of this experiment was similar to that used in Experiments III and IV. Three replicate groups of chicks were fed each diet in Experiment V. The basal diets were the same as those listed in Table 6, Experiment III.

Objective

The objective of the experiment was to compare feather meal E with the basal corn-soybean meal diets. A wide dietary protein range was used to determine what would be the effect of the "standard" feather meal in a diet adequate in protein and what its effect would be when the protein level was suboptimal.

Results and discussion

The results of this experiment show a significant difference ($P < .01$) between feather meal E and the basal diet with respect to feed conversion and weight gains. Table 9 illustrates the significant ($P < .01$) linear and quadratic effects produced by the four dietary protein levels. There was also a significant ($P < .01$) difference between the 5 and 7.5% level of added feather meal protein. This is true for both feed conversion values and weight gain data (Table 9).

The linear protein level X feather meal level interaction was significant for weight gains ($P < .01$) and feed conversion values ($P < .05$). This is explained by virtue of the great decrease in gain and feed efficiency with 7.5% feather meal protein in the 16% protein diet. In comparison with this, the diets with 5% added feather meal protein did not decrease weight gains or feed efficiency as greatly in the 16% protein diet.

Table 9. Mean weight gains to 5 weeks of age and feed conversion values ( ) - Experiment V

Diet	Dietary protein level				Means
	22%	20%	18%	16%	
Basal	749[a](1.90)[b]	815 (1.81)	623 (2.23)	621 (2.19)	702 (2.03)
F.M. E (5% prot.)	751 (1.85)	690 (2.12)	641 (2.11)	541 (2.24)	656 (2.08)
F.M. E (7.5% prot.)	605 (2.22)	657 (2.01)	576 (2.28)	267 (3.51)	526 (2.51)
Means	702 (1.99)	721 (1.98)	613 (2.21)	476 (2.65)	

[a]All values represent means of 3 replicate pens ± their standard error of 24.

[b]All values represent means of 3 replicate pens ± their standard error of 0.05.

There was a significant linear protein level X basal vs. feather meal interaction with respect to feed conversion ($P < .01$) and weight gains ($P < .05$). This interaction was also present in Experiment III and IV. It is explained by the fact that the linear protein trend is not the same with the basal diet as it was when feather meal diets were fed.

As the dietary protein was reduced from 22 to 16%, feed required per gram of gain was increased by 15.2% and gains were reduced by 17.1% when chicks were fed the corn-soybean meal diet. However, when the diets contained feather meal, the feed required per gram of gain was increased by 41.8%, and gain was reduced by 40.5% as the dietary protein was reduced from 22 to 16%. Most of this increased feed requirement and reduced gain was accounted for by the 7.5% feather meal diets. However, even when feather meal added 5% protein, feed required per gram of gain was increased by 21% and weight gains were reduced by 27.8% as the dietary protein was decreased from 22 to 16%.

This experiment supports the previous observation that feather meal E does not support growth as well as the basal except at the 22% dietary level and then only when feather meal furnishes only 5% of the protein. All other diets including feather meal E resulted in a much poorer biological response. Chicks fed the 18% protein diet with 5% added feather meal E protein, however, did respond better than those fed the basal. This is unexplainable. When comparing feather meal E to the basal diet, and feather meal D to the basal diet in Experiment IV it is quite obvious that the further-processed feather meal D has more of its amino acids made available for utilization by chicks.

The fact that very high percentages of feather meal protein in the diets decrease acceptability of the ration, as shown in Experiments I, III and IV, was also true in this experiment.

Feed efficiency data and rate of gain data demonstrated other significant sources of variation. This variation is contained in the residual of the analysis of variance table (Appendix Table 5). Upon examining the data, cubic effects can be observed. This cubic effect with its various interactions, as well as quadratic interactions, do not possess meaningful information in an experiment of this type. Consequently, these interactions were not examined individually. A detailed summary of the analysis of variance for feed conversion values and weight gain data is listed in Appendix Table 5.

Experiment VI

Experimental design

Ten seven-day-old Welp cockerels were allotted to each of 39 pens. Three replications of each of the 13 experimental treatments were maintained. Composition of the experimental diets are shown in Table 10. Twenty-one of the 39 experimental groups were fed the experimental rations from one week of age. The 7 dietary treatments applied to these were: 1. Simplified corn-soybean meal 20% protein; 2. Simplified corn-soybean meal 14% protein; 3. Diet 2+6% feather meal protein A; 4. Diet 2+6% feather meal protein B; 5. Diet 2+6% feather meal protein C; 6. Diet 2+6% feather meal protein D; 7. Diet 2+6% feather meal protein E. All

diets were isocaloric and isonitrogenous, and all were supplemented with methionine and lysine to meet NRC standards (1966). In all cases where feather meal was added, it replaced alphacel in the 14% protein basal diet. The remaining 18 groups of chicks were fed the 20% protein basal diet for the first 3 weeks and then were allotted at random (3 replicates per treatment) to treatments 2, 3, 4, 5, 6, and 7. Thus, it was possible to measure the supplementary effect of feather meal to a low-protein diet when fed to young chicks (1-4 weeks of age), in chicks fed the feather meal from 1 to 7 weeks of age, and in the 4 to 7 week age period. The cockerels were slaughtered at 8 weeks of age, and carcass yield data collected.

Objectives

The objectives of this experiment were to evaluate th effect of feather meals on weight gains, feed conversion, and carcass yield data when replacing cellulose in the diet. A second objective of this experiment was to determine whether older chicks might be able to utilize the feather meal protein more efficiently.

Results and discussion

This experiment resulted in several interesting comparisons. The mean weight gains and feed conversion values of the 21 groups fed the 20% protein corn-soybean meal diet from 1 to 4 weeks of age averaged 494 grams and 1.78, respectively. Compared with this, 15 groups fed a similar diet

Table 10. Composition of rations - Experiment VI

Ingredient	Basal-20 (%)	Basal-14 (%)	Feather meal A,B,C,D,E(%)
Ground yellow corn	65.42	70.84	70.84
Soybean meal (40%)	29.10	14.30	14.30
Feather meal	-	-	variable
Cellulose	-	5.76	variable
Soybean oil	1.00	3.20	variable
Dicalcium phosphate	1.90	2.30	2.30
Ground limestone	1.50	1.40	1.40
Salt + mineral mix[a]	0.50	0.50	0.50
Vitamin mix	0.50	0.50	0.50
Methionine hydroxy analogue	0.08	0.20	variable
Lyamine-50	-	1.00	variable
Calculated analysis:			
M.E., kcal./g.	3.07	3.07	3.07
Calcium, %	1.02	1.02	1.03
Phosphorous, %	0.70	0.70	0.75
Protein, % (Kjeldahl)	19.80	13.90	19.80

[a]See footnotes a and b, Table 2, page 26.

but with 6% protein from feather meals replacing soybean meal protein, averaged 491 grams weight gain and 1.84 grams of feed per gram gained. There were no significant differences among feather meals. However, it should be observed that feather meal E again produced slightly inferior results to other feather meals, except for feather meal C which produced the lowest weight gains (Table 11).

When considering the full 7-week period, the one highly significant ($P < .01$) difference is the improved feed conversion when the feather meals are fed only from 4 weeks onward. Diets containing feather meal in the 4-7 week period only resulted in an average weight gain of 1324

grams at 7 weeks compared with 1292 grams for the corn-soybean meal diets and 1332 grams for diets containing feather meals throughout the experimental periods. The weight gains did not differ significantly when comparing the two different periods of feeding the feather meal (Appendix Table 8). Feed conversion for the 20% protein corn-soybean groups was 2.27. For the 15 groups fed feather meal diets 1-7 weeks, the feed conversion was 2.23 and for the 15 groups fed feather meal diets in the 4-7 week period only, the feed conversion was 2.11. This difference was significant at the 0.01 level of probability (Appendix Table 8). The differences among feather meals were not significant with respect to weight gained. However, considering feed efficiency, there was a significant difference ($P < .01$) among feather meals and there was also a significant period X among feather meals interaction (Appendix Table 8). This interaction says that the differences among feather meals is not the same in each period. The differences between feather meals processed for the same amount of time (A and C vs. B and D) was significant ($P < .01$). The difference between A vs. C was also significant ($P < .05$). However, these differences did not hold true in both periods. When the chicks received feather meal in the 4-7 week period only, the feed conversion for A and C averaged 2.08, whereas, it averaged 2.16 for B and D in the same period. When the chicks were fed feather meal diets for the entire experimental period, A and C feather meals resulted in an average feed conversion value of 2.19 and feather meals B and D resulted in an average value of 2.14. Feed consumption was also affected; chicks fed feather meal 1-7 weeks of age consumed an average of 70.6 grams of feed per bird

per day and those fed feather meal from 4-7 weeks of age consumed 67.1 grams of feed per bird per day.

A summary of feed conversion values and weight gains is listed in Table 11. A detailed summary of the analysis of variances for this experiment is listed in Appendix Tables 7, 8 and 9.

It seems quite obvious that broiler chicks make more efficient use of feather meal diets when the feather meal is included after 4 weeks of age only (Table 11). It is also apparent that the chicks do not adapt to feather meal when it is included in the diet from one week of age. This is substantiated by the fact that the period X treatment interaction is not significant (Appendix Table 7). This analysis of variance compares the data from the 1-4 week period to the 4-7 week period of groups fed feather meal diets from 1-7 weeks of age. With the trend toward using more than one or two diets in producing 8-week-old broilers, it would seem feasible that the producer could introduce feather meal into his feeding regime. This could result in some valuable savings for the producer.

There are also indications in this experiment, as there were in previous experiments III, IV and V, that a simple corn-soybean meal diet (supplemented with methionine) is actually improved by the replacement of 5 or 6% feather meal protein for part of the soybean meal protein. Upon examining the amino acid levels in a feather meal-corn-soybean meal diet, it is also apparent that this diet should be supplemented with lysine in addition to methionine.

Table 11. Supplementary effect of feather meals when added to a low - protein diet - Experiment VI

Dietary protein (%)		Feather meal		Period F.M. fed (weeks)	Av. wt. gain (grams)			Feed/Gain		
1-4	4-7	(%)	Type		1-4 wks	1-7 wks	4-7 wks	1-4 wks	1-7 wks	4-7 wks
19.8	19.8	0	-	-	478±9[a]	1292±27	814±22	1.80±0.04	2.27±0.03	2.55±0.06
13.9	13.9	0	-	-	383	1118	735	2.13	2.42	2.56
19.8	19.8	6	A	1-7	485	1344	859	1.82	2.13	2.39
19.9	19.9	6	B	1-7	507	1354	847	1.82	2.21	2.45
19.8	19.8	6	C	1-7	492	1294	802	1.86	2.25	2.46
19.8	19.8	6	D	1-7	490	1351	861	1.84	2.07	2.43
19.8	19.8	6	E	1-7	482	1319	837	1.89	2.24	2.45
19.8	13.9	0	-	-	493±9	1283	790	1.79±0.04	2.23	2.50
19.8	19.8	6	A	4-7	498	1331	833	1.71	2.07	2.28
19.9	19.9	6	B	4-7	489	1316	827	1.88	2.15	2.31
19.8	19.8	6	C	4-7	504	1330	826	1.77	2.09	2.28
19.8	19.8	6	D	4-7	497	1318	821	1.77	2.17	2.40
19.8	19.8	6	E	4-7	497	1327	830	1.73	2.14	2.38

[a]All values represent means of 3 replicate groups ± their standard errors.

All feather meals supplied substantial amounts of available amino acids to the corn-soybean meal 14% protein diet. When feather meal replaced cellulose in the 14% basal diet, better weight gains and significantly better feed efficiency were attained than with the 20% corn-soybean meal diet (Appendix Tables 8 and 9).

There were no significant differences between treatments when considering the percent yielded carcass (Appendix Table 6). This indicates that the birds fed the feather meal diets produced carcasses that yielded as well as those birds fed the corn-soybean meal 20% protein diet.

Experiment VII

Experimental design

Ten seven-day-old Welp cockerels were allotted to each of 32 pens and four replicate groups were fed each of the 7 experimental rations. Experimental diets consisted of a simple corn-soybean meal ration and rations containing feather meals D or E. Each feather meal provided 3, 6 or 9% of the dietary protein, substituting for soybean meal protein. All diets were maintained isocaloric and isonitrogenous and no amino acids were supplemented. Composition of the diets is shown in Table 12. Chromic oxide was included in the rations at 0.2% to determine nitrogen retention of chicks.

During the last 72 hours of each of the 4 weekly periods, composite samples of excreta were collected in 1% HCl by placing a petri dish under each pen. Composite excreta samples were dried for 24 hours at 80°C.

Homogenized samples of the excreta were assayed for chromium and nitrogen by the previously described procedures.

Group weights and feed consumption were recorded after the chicks had been fed the experimental diets for 14 and 28 days, at which time the experiment was terminated. At this time, two birds were selected at random from each pen, weighed and their liver removed. The livers were then weighed and frozen in liquid nitrogen, and later analyzed for xanthine dehydrogenase activity.

Objective

Since previous experiments in this study indicated that the greatest differences among feather meals may exist between feather meals D and E, it seemed reasonable to do an experiment where these feather meals were fed over a wider protein range in the diet (3, 6 and 9%). This should give a more accurate account as to the differences, if there are any, that exist between these two feather meals in eliciting a biological response. A nitrogen retention study was incorporated to more specifically determine amino acid availability from the feather meals when used over the wider range in the diet.

As an additional method to assist in measuring the quality of the two feather meal diets, xanthine dehydrogenase assays were used. This is justifiable by the fact that this enzyme is considered adaptable to protein intake (Stripe and Corte 1965, Scholz and Featherston 1968) and may also be an indicator of protein quality (Kazemi-Shirazi 1972).

Table 12. Composition of rations - Experiment VII

Ingredient		Protein from feather meal		
		3%	6%	9%
	(%)	(%)	(%)	(%)
Ground yellow corn	57.40	60.60	63.70	66.65
Soybean meal	35.30	28.15	21.50	15.00
Feather meal (D or E)	-	3.65	7.20	10.75
Dicalcium phosphate	1.60	1.90	1.90	1.90
Ground limestone[a]	1.50	1.50	1.50	1.50
Salt + mineral mix[a]	0.50	0.50	0.50	0.50
Vitamin mix	0.50	0.50	0.50	0.50
Soybean oil	3.00	3.00	3.00	3.00
Cr_2O_3	0.20	0.20	0.20	0.20
Calculated analysis:				
M.E., kcal./g.	3.14	3.14	3.16	3.17
Calcium, %	0.97	1.00	1.01	1.02
Phosphorous, %	0.66	0.70	0.71	0.71
Protein, % (Kjeldahl)	21.9	21.8	21.8	21.75

[a]See footnotes a and b, Table 2, page 26.

Results and discussion

Upon examining all parameters measured in this experiment, there were no significant differences between feather meals D and E. The basal diet produced significantly better weight gains ($P < .01$), feed efficiency ($P < .01$) and increased xanthine dehydrogenase activity in the liver ($P < .01$), when compared with all diets containing feather meal. The basal diet resulted in only a slight increase in nitrogen retention over the feather meal diets, when averaged over the four collection periods. However, within the feather meal diets considering weight gains, feed efficiency and nitrogen retained, there was a significant linear and

quadratic effect produced by the three feather meal protein levels (Figure 2 and 3). The quadratic effect was caused by the greatly deleterious effect of the 9% feather meal diet for the three respective parameters. There was also a significant ($P < .05$) linear effect among the feather meal levels with respect to the xanthine dehydrogenase activity (Figure 2). There were no significant differences with respect to liver weights in this experiment, although the higher feather meal levels tended to decrease liver weights (Table 13). Appendix Tables 10, 11, 12 and 13 give detailed summaries of the analysis of variance for these parameters.

When considering the percent nitrogen retained, there was also a significant ($P < .01$) feather meal type X linear feather meal level interaction. Therefore, when examining the linear feather meal trend, with respect to nitrogen retention data, one must also consider the feather meal type (Figure 3). Figure 3 illustrates that the percent nitrogen retained from diets containing feather meal E is quite high when it is supplied at the 3 and 6% protein levels. However, when 9% of the dietary protein is supplied by feather meal E, a marked decrease in nitrogen retention is observed. A corresponding decrease in weight gains is also seen with respect to feather meal E (Table 13). When feather meal D protein was increased from 3 to 9%, the weight gains decreased on the average by 38.4% and the nitrogen retained decreased by 9.1%. However, most of this was due to the 9% feather meal level. When feather meal protein D was increased from 6 to 9%, the weight gains decreased an average of 36.6% and the nitrogen retained decreased by 10.6%. When feather meal E was

increased from 3 to 9%, the average decrease in weight gains was 39.8% and the nitrogen retained decreased an average of 53.6%. However, with feather meal E, even more of the decreased nitrogen retention was due to the 9% protein level. When feather meal E protein was increased from 6 to 9%, the weight gains decreased an average of 39.4% and the nitrogen retained decreased 46.5%. These differences between the two feather meals are illustrated in Figure 3. This might be an indication that the birds fed feather meal E were depositing more fat or retaining more water than those fed feather meal D.

With respect to nitrogen retention data, there was also a period X treatment interaction ($P < .01$). This is explained by the fact that the basal diets consistently resulted in more nitrogen being retained than did the feather meal diets with the exception of the third period, where the basal diets resulted in less nitrogen retained. It is also obvious that the chicks did not retain the nitrogen from feather meal diets as readily as when the nitrogen primarily was derived from corn and soybean meal when the chicks are at one or two weeks of age. This is illustrated in Figure 4.

Among groups fed feather meal diets, protein intake per bird per day decreased by 21.1% when feather meal was increased from 3 to 9% of the protein. However, most of this decreased protein intake was due to the 9% protein level. When feather meal protein was increased from 6 to 9%, the protein intake decreased an average of 17.2%.

It appears that the xanthine dehydrogenase activity decreased much more rapidly than the protein intake decreased. As the feather meal

Table 13. Effect of feather meal process on weight gains, feed conversion, xanthine dehydrogenase activity, liver weights, and nitrogen retention to 5 weeks of age - Experiment VII

Diet	Weight gains (g.)	Feed/gain	Xanthine[c] dehydrogenase	Liver[d] wt. (%)	Nitrogen retention (%)
Basal	700±13[a]	1.88±0.06	940±90	2.32±0.11	44.3±2.1
F.M. D-3% prot.	701±18[b]	1.90±0.09	735±127	2.63±0.16	42.7±2.9
F.M. D-6% prot.	682	1.92	539	2.47	43.4
F.M. D-9% prot.	432	2.51	522	2.10	38.8
F.M. E-3% prot.	693	1.88	798	2.32	54.3
F.M. E-6% prot.	689	1.87	518	2.67	47.1
F.M. E-9% prot.	418	2.50	468	2.23	25.2
Means					
F.M. D & E 3% prot.	697	1.89	766	2.47	48.5
F.M. D & E 6% prot.	686	1.89	528	2.57	45.2
F.M. D & E 9% prot.	425	2.30	495	2.17	32.0
F.M. D (3,6 & 9% prot.)	605	2.11	599	2.40	41.6
F.M. E (3,6 & 9% prot.)	600	2.08	595	2.41	42.2

[a]All values represent means of 8 replicate pens ± their standard error.

[b]All values represent means of 4 replicate pens ± their standard error.

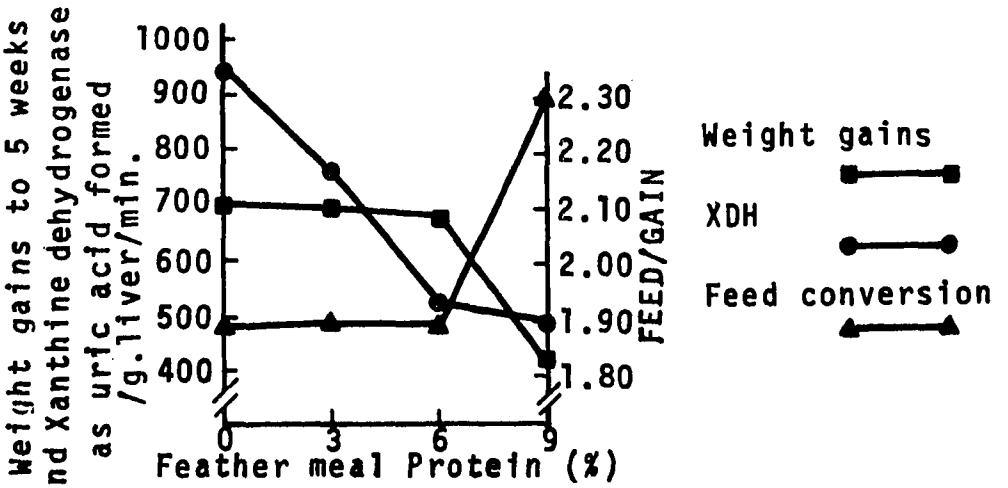
[c]Micromoles of uric acid formed/g. tissue/minute.

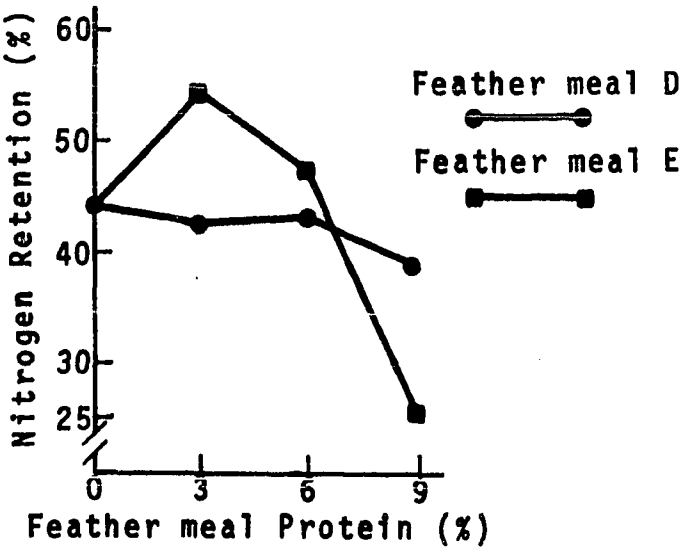
[d]Percentage of body weight.

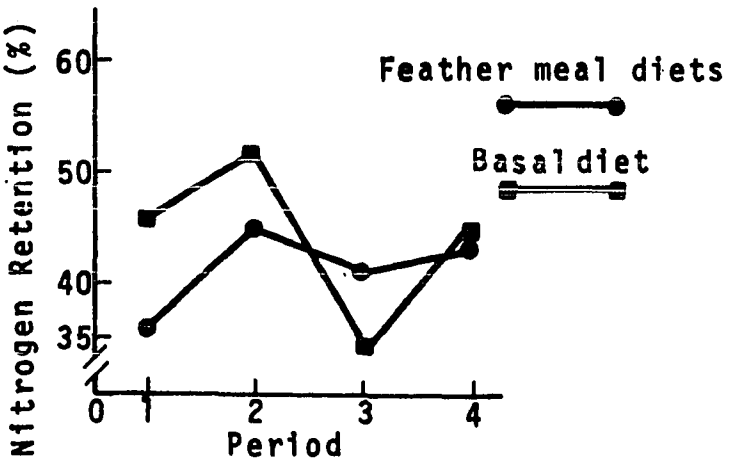
Figure 2. Mean net change in weight gains to 5 weeks of age, xanthine dehydrogenase activity, and feed conversion values

Figure 3. Mean net change in nitrogen retention values as effected by feather meal type and feather meal level

Figure 4. Mean net change in nitrogen retention over a four week period


Weight gains to 5 weeks and Xanthine dehydrogenase as uric acid formed /g.liver/min.
1000
900
800
700
600
500
400
2.30
2.20
2.10
2.00
1.90
1.80
FEED/GAIN
0
3
6
9
Feather meal Protein (%)
Weight gains
XDH
Feed conversion


Nitrogen Retention (%)
60
50
40
30
25
0
3
6
9
Feather meal Protein (%)
Feather meal D
Feather meal E


Nitrogen Retention (%)
60
50
40
35
0
1
2
3
4
Period
Feather meal diets
Basal diet

protein level was increased from 3 to 9%, xanthine dehydrogenase activity decreased an average of 35.4%, whereas, protein intake decreased, on the average, by only 21.1% per bird per day. However, when feather meal protein was increased from 3 to 6%, the xanthine dehydrogenase activity decreased by 31%, but the protein intake decreased only an average of 4.6% per bird per day. When feather meal protein was increased from 6 to 9% in the diets, xanthine dehydrogenase activity decreased only by 6.7%. Protein intake was affected the greatest here and decreased on the average by 17.2%. These data tend to indicate that the xanthine dehydrogenase activity may be affected more by the quality of the protein taken in rather than the quantity.

Experiment VIII

Experimental design

Five seven-day-old Welp cockerels were individually weighed and allotted to each of 28 pens. Four replicate groups of chicks were fed each of the 7 experimental diets. One experimental diet consisted of corn and soybean meal, while another diet was protein free. The other experimental diets were semisynthetic diets with all of the protein derived from feather meals A, B, C, D or E. Methionine and lysine were added to all diets, with the exception of the protein-free diet, to meet NRC standards for these two amino acids. The experimental diets are shown in Table 14.

This experiment applied the carcass analysis method to chicks for determining net protein value as outlined by Summers and Fisher (1961).

Chicks were maintained on the experimental rations for two weeks, at which time they were weighed and feed consumption recorded. To prevent feed loss, extra care was taken by filling feeders only one quarter full and a collection tray was placed under the feed to collect any feed pecked out by the chicks. Feed collection in this lower tray was collected each day and weighed at the end of the experiment.

Objective

The objective of this experiment was to determine the net protein value of five feather meals processed differently and to determine the net protein value of a simple corn-soybean protein mixture. The corn-soybean protein diet was incorporated into the design to check the accuracy of experimental methods. Fisher et al. (1962) and Summers and Fisher (1962) reported that repeatability of this method is excellent between experiments.

Results and discussion

The results of this experiment indicate that feather meals supplemented with methionine and lysine do not support good growth when fed as the sole protein source and that they result in low NPV. There were no significant NPV differences among feather meals. A summary of the analysis of variance is presented in Appendix Table 14. Figure 5 illustrates what has been observed in previous experiments, that feather meal E may be inferior to the other feather meals. The NPV means also tend to show

Table 14. Composition of rations - Experiment VIII

Ingredients	Diets						
	Protein free (%)	Corn-soybean (%)	A (%)	B (%)	C (%)	D (%)	E (%)
Dextrose	87.50	-	69.56	69.08	69.30	69.22	69.09
Corn	-	75.76	-	-	-	-	-
Soybean meal	-	13.00	-	-	-	-	-
Feather meal[a]	-	-	15.40	15.60	15.70	15.70	15.70
Soybean oil	1.00	2.00	3.00	3.00	3.00	3.00	3.00
Cellulose	5.00	1.00	3.00	3.00	3.00	3.00	3.00
Methionine hydroxy-analogue	-	0.46	0.44	0.63	0.40	0.68	0.61
Lyamine-50	-	1.00	2.10	2.19	2.10	1.90	2.10
Vitamin mixture[b]	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Trace mineral mixture[c]	6.00	6.00	6.00	6.00	6.00	6.00	6.00

[a]Type of feather meal added corresponds to the diet identification.

[b]Supplies the following vitamins per kg. of diet - A 10,000 IU; D_3 900 IU; E 10 IU; K 1 mg.; thiamine 2 mg.; riboflavin 5 mg.; calcium pantothenate 10 mg.; niacin 30 mg.; pyridoxine 4 mg.; biotin 100 mcg.; folic acid 1.2 mg.; B_{12} 10 mcg.; choline 1300 mg.; ascorbic acid 250 mg.

[c]Fox and Briggs (19[illegible]) salt mixture. Supplies the following minerals - calcium 1.24%; phosphorous 0.8%; potassium 0.37%; sodium 0.38%; chlorine 0.58%; magnesium 600 mg./kg.; iron 80 mg./kg.; manganese 81 mg./kg.; iodine 6 mg./kg.; zinc 73 mg./kg.; copper 4 mg./kg.

feather meal D slightly superior to all other feather meals (Figure 5). This, too, has been shown in the other experiments. More detailed data on the NPV means are listed in Appendix Table 15.

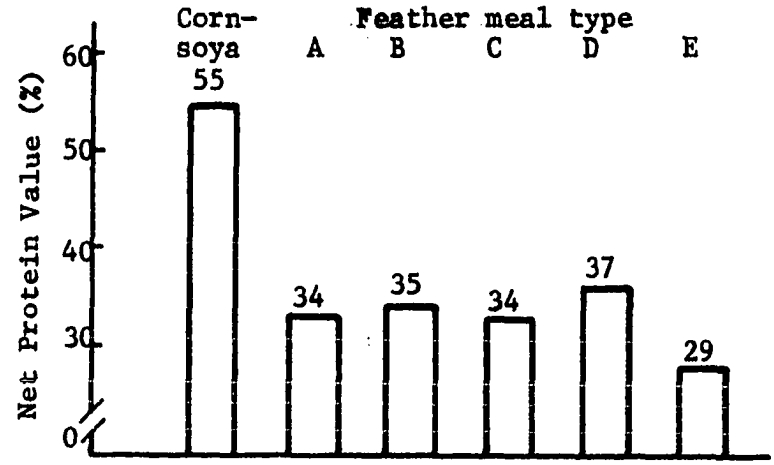


Figure 5. Net protein values of five differently processed feather meals and a corn-soybean diet

The net protein values obtained in this experiment for the corn-soybean meal diet and the feather meal diets were commensurate to those derived by Fisher et al. (1962). Their net protein value for feather meal was 26.3% and 56.1% for a corn-soybean meal diet, whereas, in Experiment VIII, NPV data averaged 34% for feather meal diets and 55% for the corn-soybean meal diet. The probable reason for our higher NPV for feather meal is due to the supplemented methionine and lysine. Fisher et al. (1962) did not supplement their feather meal diets with methionine or lysine. However, Fisher and Griminger (1969) showed the NPV of ground nut meal diets is improved by the supplementation of lysine and methionine. It appears from these data that feather meal protein, on the average, has a net protein value about 62% of the corn-soybean meal diet.

GENERAL DISCUSSION

Feather meal has been shown to be a valuable protein source when used to replace a limited amount of soybean meal in a simple corn-soybean meal ration. Levels of feather meal protein should not exceed 5% in a corn-soybean meal diet when no amino acids are supplemented to the diet. If methionine and lysine are supplemented to the diet, it is feasible to include 5 or 6% feather meal protein in the diet. With the current practice to supplement methionine and the trend to supplement lysine into poultry diets, feather meal could be an adequate substitute for other more valuable protein sources. When feather meal protein is supplemented at the 7.5% level, gains, feed efficiencies and feed consumption were greatly reduced regardless of methionine and lysine supplementation. At this high level, the diets most probably became deficient in tryptophan and histidine. These two amino acids are considered to be the third and fourth most limiting amino acids, while methionine and lysine are considered the first and second most limiting amino acids in feather meal protein, respectively (Moran et al. 1966).

This research substantiates the findings of Sibbald et al. (1962) and Tsang et al. (1963), showing that feather meal can comprise a larger percentage of high protein diets (22-20%) as compared with low protein diets (18-16%). This is important to the broiler industry since they are primarily concerned with high protein diets. With a 24% protein diet, which is not uncommon for a broiler starter diet, the percent feather meal protein that could be added might even be higher than the 5 or 6%

levels shown in these experiments. However, the results of this study indicate that when more than 5 or 6% feather meal protein was incorporated into the diet at 1 week of age, a decrease in feed efficiency resulted. High levels of feather meal also decrease the palatibility of the ration and this resulted in decreased feed consumption. Decreased feed efficiency from feather meal protein can be overcome by including the feather meal in the diets after the chicks are 4 to 5 weeks of age.

Among the feather meal processes investigated, it appears difficult to show any significant differences with respect to the parameters measured in these experiments. Upon observing the small differences between the feather meals' pepsin digestibility and amino acid composition, this is not surprising. Naber et al. (1961) showed that if feather meal samples had pepsin digestibilities with differences of a greater magnitude than what our samples indicated, the processing method employed could affect the nutritive value of the feather meal. Therefore, the processes we investigated were probably not different enough to result in significant differences between weight gains and feed efficiency. Sullivan and Stephenson (1957) also showed that the differences in growth response and feed efficiency were small when they investigated seven different processing methods.

There were definite trends, however, that are evident throughout this series of 8 experiments. Feather meal that had been further processed than what is considered "standard" today tended to increase weight gains and resulted in slightly better feed efficiency. The further processed feather meal also resulted in higher net protein values than the

"standard" process. Since the further-processed feather meals were intermittently agitated and the "standard" process involved constant agitation, it can also be concluded that the intermittent agitation may have some beneficial effect.

When feather meal protein was added at the 5 and 7.5% level in the 22 and 20% protein diets, feather meal D produced equivalent or better results than the corn-soybean diet in Experiment IV. That feather meal E produced inferior results when compared to the corn-soybean meal diet in the same type of experiment is of importance in this study. Only when feather meal E protein was supplemented at the 5% level in the 22% protein diet did it produce better results than the corn-soybean diets. These data clearly show that feather meal D was capable of replacing more of the soybean meal in optimal or suboptimal protein diets than was feather meal E. This same observation was true for feather meal C, except when considering it, one must only consider the 5% protein level. Feather meal C did not produce equivalent results to the corn-soybean meal diets when added at the 7.5% level, with the exception of the 22% protein diet where it resulted in better weight gains and feed efficiency than the corn-soybean meal diets.

Feather meal A, which was processed under the mildest conditions of the new processes, did not produce weight gains or feed efficiency equivalent to the corn-soybean meal diets at either the 5 or 7.5% protein levels in the optimal protein diets. However, in the 16% protein diet, the 5% protein level did produce better weight gains than the 16% corn-soybean meal diets. Feather meal B, when added at the 5% protein level to both

optimal and suboptimal protein diets, did produce results almost equivalent to the corn-soybean meal diets. It also produced better weight gains and feed efficiency than the corn-soybean meal diets when supplemented at the 5% protein level in the 16% protein diets. These results indicated that further processing of the feather meal may be required to release more of the potentially available amino acids present in feathers.

It was quite apparent from Experiment VI that older chicks made more efficient use of feather meal protein. Nitrogen retention data also indicated that chicks do not utilize feather meal protein as well as corn-soybean protein at a very early age. Chicks at 2 and 3 weeks of age fed feather meal diets did not retain the nitrogen as readily as chicks fed the corn-scybean meal diets. However, as the chicks grew older their nitrogen retention was equivalent to that of chicks fed the corn-soybean meal diet. This again demonstrated that in a broiler feeding regime it would be more feasible to include feather meal in the diets after 4 or 5 weeks of age. Gehle et al. (1967) also found hydrolyzed hog hair was better utilized by older chicks. Our results indicated that young chicks do not adapt to feather meal protein when it is included in their diet at an early age. Gehle et al. (1967) also found this to be true with hydrolyzed hog hair.

In avian species, the primary nitrogen excretory product resulting from protein and amino acid catabolism is uric acid. The end reactions involved in the biosynthesis of this purine (hypoxanthine → xanthine → uric acid) are catalyzed by a NAD - dependent xanthine dehydrogenase.

This enzyme is considered an adaptable enzyme (Stripe and Corte 1965, Scholz and Featherston 1968). Therefore, as more protein is absorbed from the intestine and catabolized, the activity of this enzyme is increased. From our data, the highest xanthine dehydrogenase activity was associated with the corn-soybean meal diets. However, protein intake was the same for the 3 and 6% feather meal protein diets as it was for the soybean meal diets. This indicated a greater excess of amino acids was absorbed and catabolized by chicks fed the corn-soybean meal diets. The abrupt decrease in xanthine dehydrogenase activity when 3 and 6% feather meal protein diets were fed as compared with the corn-soybean meal indicates that fewer excess amino acids were absorbed and catabolized from the feather meal diets. However, at the 3% feather meal protein level, neither weight gains or feed efficiency were depressed. This indicated that the amino acid balance of this diet was satisfactory.

When protein intake was constant, the xanthine dehydrogenase activity seemed to be a good measure of amino acids available for absorption by the chick in excess, optimal or suboptimal amounts to the chick's requirement. The decreased xanthine dehydrogenase activity when 9% feather meal protein diets were fed can be accounted for by the decreased protein intake.

When feather meal E was supplying 6 or 9% of protein to the diet, it produced lower xanthine dehydrogenase activity than did feather meal D protein fed at the same levels. It would appear that feather meal E had less amino acids available for absorption than did feather meal D. This

supported the data listed in Table 1. Feather meal E had lower pepsin digestibility and a lesser amount of total amino acids when compared with feather meal D. Feather meal E also had a lower available lysine value when compared with feather meal D.

Xanthine dehydrogenase activity was probably not as sensitive an assay as is required to distinguish between two closely related protein sources, such as feather meal D and E. But it was sensitive enough to exhibit differences between different categories of protein sources where an excess or deficiency of amino acids existed.

In all the experiments of this study where feather meal D was compared with feather meal E, there was a definite trend for feather meal D to produce slightly superior results. Feather meal D resulted in the highest net protein value of all the feather meals investigated. From the xanthine dehydrogenase data, feather meal D appeared to have more available amino acids for absorption by the chick than did feather meal E. When feather meal D replaced all of the soybean meal protein in the diet, it resulted in slightly better gains and feed efficiency than any of the other feather meals which were processed by the new procedures. Chemical analysis of the feather meals also tended to support feather meal D as the superior protein source. Therefore, we can conclude from this study of 8 experiments that a feather meal processed at 50 pounds of steam pressure for 60 minutes with intermittent agitation produced the best biological response from broiler chicks.

SUMMARY AND CONCLUSIONS

1. Feather meal protein should not exceed 5% of the diet in a corn-soybean meal diet when no amino acids are supplemented to the diet.
2. Feather meal protein may substitute for soybean meal at a level of 5 to 6% when the diet is supplemented with methionine and lysine, with no more than 6% feather meal protein, regardless of methionine and lysine supplementation.
3. If feasible, chicks should be fed a diet containing feather meal only after 4 or 5 weeks of age.
4. Of the lysine present in the feather meals, on the average, 72.5% of it is "available lysine". The further-processed feather meals (C and D) contain more free lysine than do the feather meals processed under milder conditions (A and B).
5. Feather meal samples do not differ greatly enough in pepsin digestibility to make valid conclusions on this basis. However, the further-processed feather meals tend to have slightly higher pepsin digestibility.
6. Further-processed feather meals with intermittent agitation tended to increase the chick's biological response throughout this series of experiments compared with chicks fed diets containing a "standard" feather meal.
7. It appears that the "standard" process (feather meal E) does not release the maximum amount of amino acids that are potentially available in the feathers, as well as does further processing. Feather

meal D contains more free methionine, lysine and histidine when compared with the other feather meals.

8. Nitrogen retention decreased linearly when feather meal protein was added to the diet from 3 to 9%. However, only with the 9% feather meal protein level was a marked decrease in nitrogen retention observed.
9. The "standard" processed feather meal E resulted in a lower net protein value than any of the other further-processed feather meals. Feather meal D produced the highest net protein value of all the feather meals.
10. Feather meal protein added to a corn-soybean meal diet at 6% does not have a deleterious effect on carcass yields.
11. The process that resulted in the best biological responses from broiler chicks was as follows: Feathers were cooked at 50 pounds of steam pressure for 60 minutes with intermittent agitation (agitate 1 min. stop 1 min.), dry and grind.

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APPENDIX

Table 1. Analysis of variance of weight gain and feed conversion in Experiment I

Source of variation	Weight gains			Feed/gain		
	d.f.	M.S.	F statistic	d.f.	M.S.	F statistic
Treatment	4	111848	763**	4	128.72	37.64**
Basal vs feather meals	(1)	447155	3052**	(1)	116.76	34.14**
Among feather meals	(3)	68.1	n.s.	(3)	4.04	n.s.
Error	10	146.5		10	3.42	

*Probability 0.05 or less here and throughout.

**Probability 0.01 or less here and throughout.

Table 2. Analysis of variance of weight gain and feed conversion in Experiment II

Source of variation	Weight gain			Feed/gain		
	d.f.	M.S.	F statistic	d.f.	M.S.	F statistic
Treatment	10	11550	10.1**	10	0.0214	n.s.
Basal vs feather meals	(1)	988	n.s.	(1)	0.0084	n.s.
F.M.E. vs other feather meals	(1)	5945	5.19*	(1)	0.0048	n.s.
F.M.E. levels	(1)	852	n.s.	(1)	0.0090	n.s.
(L) F.M.A,B,C,D levels	(1)	1792	n.s.	(1)	0.0012	n.s.
(T) 30 min vs 60 min process	(1)	83	n.s.	(1)	0.0113	n.s.
(P) 40 psi vs 50 psi process	(1)	0.11	n.s.	(1)	0.0193	n.s.
T X P	(1)	54	n.s.	(1)	0.0011	n.s.
L X T	(1)	80	n.s.	(1)	0.0368	n.s.
L X T X P	(1)	1693	n.s.	(1)	0.0074	n.s.
Error	22	1145		22	0.0351	

Table 3. Analysis of variance of weight gain and feed conversion in Experiment III

Source of variation	Weight gain			Feed/gain		
	d.f.	M.S.	F statistic	d.f.	M.S.	F statistic
Treatment	19	35043	10.7**	19	0.213	42.6**
F.M. type (A vs B)(T)	(1)	173	n.s.	(1)	0.025	5.00*
Protein level$_L$ (P_L)	(1)	344616	105.3**	(1)	1.831	366.2**
Protein level$_Q$ (P_Q)	(1)	91518	27.9**	(1)	0.519	103.8**
Basal vs feather meals	(1)	34674	10.6**	(1)	0.001	n.s.
Feather meal levels (5 vs 7.5)(L)	(1)	92085	28.1**	(1)	0.441	88.2**
T X L	(1)	755	n.s.	(1)	0.441	88.2**
T X P_L	(1)	5302	n.s.	(1)	0.042	8.4**
P_L X L	(1)	73428	22.4**	(1)	0.479	95.8**
P_L X L X T	(1)	78400	23.9**	(1)	0.029	5.8*
P_L X Basal vs feather meals	(1)	3062	n.s.	(1)	0.025	5.0*
Residual	(9)	1684	n.s.	(9)	0.0237	4.74**
Error	20	3274		20	0.005	

Table 4. Analysis of variance of weight gain and feed conversion in Experiment IV

Source of variation	Weight gain			Feed/gain		
	d.f.	M.S.	F statistic	d.f.	M.S.	F statistic
Treatment	19	35847	18.6**	19	0.706	40.11**
F.M. type (C vs D)(T)	(1)	9807	5.10*	(1)	0.898	51.02**
Protein level$_L$ (P_L)	(1)	268414	139.46**	(1)	3.661	208.01**
Protein level$_Q$ (P_Q)	(1)	51072	19.12**	(1)	1.444	82.05**
Basal vs feather meals	(1)	23141	12.02**	(1)	0.344	19.55**
Feather meal levels (5 vs 7.5)(L)	(1)	126555	65.75**	(1)	2.040	115.92**
T X L	(1)	5020	n.s.	(1)	0.177	10.1**
T X P_L	(1)	3936	n.s.	(1)	0.708	40.2**
P_L X L	(1)	122467	63.63**	(1)	1.936	110.0**
P_L X L X T	(1)	8188	n.s.	(1)	0.482	27.39**
P_L X Basal vs feather meals	(1)	36807	26.54**	(1)	0.483	27.45**
Residual	(9)	2855	n.s.	(9)	7.83	7.83*
Error	20	1925		20	0.0176	

Table 5. Analysis of variance of weight gain and feed conversion in Experiment V

Source of variation	Weight gain			Feed/gain		
	d.f.	M.S.	F statistic	d.f.	M.S.	F statistic
Treatment	11	57544	33.9	11	0.580	85.3**
Protein level$_L$ (P_L)	(1)	275538	162.5**	(1)	2.171	319.5**
Protein level$_Q$ (P_Q)	(1)	54546	32.5**	(1)	0.456	67.0**
Basal vs feather meal	(1)	98524	58.1**	(1)	0.541	79.0**
Feather meal levels (5 vs 7.5)(L)	(1)	101478	59.8**	(1)	1.084	159.0**
P_L X L	(1)	13217	7.8*	(1)	0.660	97.0**
P_Q X L	(1)	39317	23.2**	(1)	0.936	137.6**
P_L X Basal vs feather meal	(1)	9678	5.71*	(1)	0.185	27.2**
Residual	(4)	10172	5.99**	(4)	0.086	12.6**
Error	24	1696		24	0.0068	

Table 6. Analysis of variance of percent carcass yield data in Experiment VI

Source of variation	d.f.	M.S.	F statistic
Treatment	12	18.98	n.s.
Error	143	4177.22	

Table 7. Analysis of variance of weight gain and feed conversion in Experiment VI, comparing data from the 1-4 week period to the data from the 4-7 week period, when feather meal diets were fed 1-7 weeks

Source of variation	Weight gains			Feed/gain		
	d.f.	M.S.	F statistic	d.f.	M.S.	F statistic
Treatment (T)	6	10294	9.77	6	0.039	6.50
20% basal vs. feather meals	(1)	2099	n.s.	(1)	0.0061	n.s.
14% basal vs. feather meals	(1)	57783	54.8**	(1)	0.210	35.00**
Among feather meals	(4)	984	n.s.	(4)	0.0036	n.s.
Error a (R/T)	14	1054	n.s.	14	0.006	n.s.
Period (P)	1	1273718	2262**	1	3.681	525.7**
PXT	6	721	n.s.	6	0.012	n.s.
Error	14	563		14	0.007	

Table 8. Analysis of variance of weight gains and feed conversion - Experiment VI. Comparing chicks fed experimental diets in 1-7 week period to data from chicks fed the experimental diets in the 4-7 week period

Source of variation	Weight gains			Feed/gain		
	d.f.	M.S.	F statistic	d.f.	M.S.	F statistic
Treatment	12	11109	5.04**	12	0.0316	9.58**
20% basal vs. feather meals	(1)	3780	n.s.	(1)	0.272	8.24**
14% basal vs. feather meals	(1)	82986	37.63**	(1)	0.1204	36.48**
Among feather meals	(4)	2226	n.s.	(4)	0.0484	14.67**
A,B,C,D vs. E	-	-	-	(1)	0.0016	n.s.
A,C vs. B,D	-	-	-	(1)	0.0360	10.91**
A vs C	-	-	-	(1)	0.0147	4.45*
B vs D	-	-	-	(1)	0.0126	n.s.
Period (P)	(1)	4077	n.s.	(1)	0.1560	47.27**
P X 14% basal vs. feather meals	(1)	37178	16.9**	(1)	0.0061	n.s.
P X among feather meals	(4)	4280	n.s.	(4)	0.0145	4.39**
Error	26	2205		26	0.0033	

Table 9. Analysis of variance of weight gain and feed conversion in Experiment VI. Comparing 4-7 week data of chicks fed experimental diets the full 1-7 week period to the 4-7 week data of those chicks fed experimental diets the last 4-7 week period

Source of variation	Weight gain			Feed/gain		
	d.f.	M.S.	F statistic	d.f.	M.S.	F statistic
Treatment (T)	12	3336	2.32*	12	0.0248	2.58*
20% basal vs. feather meals	(1)	1320	n.s.	(1)	0.0742	7.23*
14% basal vs. feather meals	(1)	27158	18.89**	(1)	0.1051	10.95**
Among feather meals	(4)	2227	n.s.	(4)	0.0072	n.s.
Period (P)	(1)	13	n.s.	(1)	0.0812	8.46**
P X 14% basal vs. feather meals	(1)	5645	n.s.	(1)	0.0022	n.s.
P X among feather meals	(4)	2184	n.s.	(4)	0.0165	n.s.
Error	26	1437		26	0.0096	

Table 10. Analysis of variance of xanthine dehydrogenase in Experiment VII

Source of variation	d.f.	M.S.	F statistic
Treatment	6	186218	2.89*
Basal vs. factorial	(1)	744833	11.54**
Factorial	(5)	72857	n.s.
F.M. type (T)	(1)	104	n.s.
F.M. $level_L$ (L_L)	(1)	297121	4.60*
F.M. $level_Q$ (L_Q)	(1)	60510	n.s.
T X L_L	(1)	13865	n.s.
T X L_Q	(1)	876	n.s.
Error	25	64522	

Table 11. Analysis of variance of weight gain and feed conversion in Experiment VII

Source of variation	Weight gains			Feed/gain		
	d.f.	M.S.	F statistic	d.f.	M.S.	F statistic
Treatment	6	72726	54.1**	6	0.374	11.33**
Basal vs. factorial	(1)	56163	41.8**	(1)	0.2688	8.15**
Factorial	(5)	75892	56.5**	(5)	0.395	11.97**
F.M. type	(1)	138.2	n.s.	(1)	0.004	n.s.
F.M. $level_L$	(1)	295883	220.2**	(1)	1.480	44.85**
F.M. $level_Q$	(1)	82967	61.7**	(1)	0.488	14.79**
Type X $level_L$	(1)	32.5	n.s.	(1)	0.0001	n.s.
Type X $level_Q$	(1)	439	n.s.	(1)	0.002	n.s.
Error	25	1344		25	0.033	

Table 12. Analysis of variance of % nitrogen retention in Experiment VII

Source of variation	d.f.	M.S.	F statistic
Treatment (T)	6	1313.05	9.70**
Basal vs. factorial	(1)	144.8	n.s.
Factorial	(5)	1499.2	11.08**
Type	(1)	7.09	n.s.
$Level_L$	(1)	4281.2	31.64**
$Level_Q$	(1)	550.5	4.07*
Type X $level_L$	(1)	2532.1	18.71**
Type X $level_Q$	(1)	124.9	n.s.
Error (a)(R/T)	21	135.3	4.4**
Period	3	411.2	13.35**
T X P	18	89.8	2.92**
Error (b)	79	30.8	

Table 13. Analysis of variance of liver weights (% of body weight) in Experiment VII

Source of variation	d.f.	M.S.	F statistic
Treatment	6	0.3641	n.s.
Basal vs. factorial	(1)	0.101	n.s.
Factorial	(5)	0.423	n.s.
Type	(1)	0.031	n.s.
$Level_L$	(1)	0.769	n.s.
$Level_Q$	(1)	0.640	n.s.
Type X $level_L$	(1)	0.353	n.s.
Type X $level_Q$	(1)	0.224	n.s.
Error (a)(R/T)	25	0.210	1.98*
Error (b)	32	0.106	

Table 14. Analysis of variance of net protein value in Experiment VIII

Source of variation	d.f.	M.S.	F statistic
Treatment	5	333.93	12.1**
Corn-soya vs. feather meals	(1)	1532.3	55.5**
Among feather meals	(4)	34.88	n.s.
Error	18	27.6	

Table 15. Net protein value means - Experiment VIII

Diet	A	B	C	D	E	Corn-soya
Replicate 1)	36.0	29.4	35.9	38.1	24.3	60.1
2)	30.0	38.9	33.6	32.3	27.7	52.2
3)	30.2	36.8	36.7	33.7	23.3	58.7
4)	41.1	33.8	31.4	44.4	40.9	50.2
Mean	34.3[a]	34.7	34.4	37.1	29.0	55.3

[a]All values represent means $\pm$ their standard error of 2.6.